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Report to the Federal Power Commission

Washington

1923

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Box 137 U. S. *Federal power commission.*
... Report to the Federal power commission on the uses of the upper Columbia River ... Washington, Govt. print. off., 1923.
viii, 98 p. incl. tables. diagrs. (part col.) charts (part col.) 25cm.
At head of title: Federal power commission.
Report made by a board of engineers consisting of J. B. Cavanaugh, colonel, Corps of engineers, chairman, D. C. Henny, consulting engineer, United States Reclamation service, Fred F. Henshaw, district engineer, United States Geological survey, W. G. Swendsen, commissioner, Department of reclamation, Idaho, C. S. Heidel, state engineer, Montana, and Marvin Chase, supervisor of hydraulics, Washington state.
1. Columbia River. I. Cavanaugh, James Bates, 1869– II. Henny, David Christian. III. Henshaw, Fred Forbes, 1884– IV. Heidel, Charles Sumner. V. Swendsen, Warren G. VI. Chase, Marvin.
D628.1 Un324
Copy in Engineering Reading Room.
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FEDERAL POWER COMMISSION

REPORT

TO THE

FEDERAL POWER COMMISSION

ON THE

USES OF THE UPPER COLUMBIA RIVER

BOARD OF ENGINEERS

J. B. CAVANAUGH - - - - - - Colonel, Corps of Engineers, U. S. Army
D. C. HENNY - - - - - Consulting Engineer, U. S. Reclamation Service
F. F. HENSHAW - - - - - - District Engineer, U. S. Geological Survey
C. S. HEIDEL - - - - - - - - - - - - - - - - - - State Engineer, Montana
W. G. SWENDSEN - Commissioner, Department of Reclamation, Idaho
MARVIN CHASE - - - Supervisor of Hydraulics, State of Washington

WASHINGTON
GOVERNMENT PRINTING OFFICE
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FEDERAL POWER COMMISSION.

THE SECRETARY OF WAR, *Chairman.*
THE SECRETARY OF THE INTERIOR. THE SECRETARY OF AGRICULTURE.
O. C. MERRILL, *Executive Secretary.*

W.R. 9 Aug. 1923

LETTERS OF TRANSMITTAL.

WASHINGTON, D. C., *February 17, 1923.*

DEAR MR. SECRETARY: I submit to you herewith report of the Columbia River board containing a study of and recommendations upon a general plan of development of the Columbia River between Flathead Lake in Montana and the mouth of the Snake River in Washington.

By the provisions of the Federal water power act the commission is authorized and empowered "to make investigations and to collect and record data concerning the utilization of the water resources of any region to be developed, the water-power industry, and its relation to other industries and to interstate or foreign commerce," "to cooperate with the executive departments and other agencies of State or National Governments in such investigations," and "to make public from time to time the information secured." The act further provides that all licenses issued thereunder shall be on the condition "that the project adopted, including the maps, plans, and specifications, shall be such as in the judgment of the commission will be best adapted to a comprehensive scheme of improvement and utilization for the purpose of navigation, of water-power development, and of other beneficial public uses; and, if necessary, in order to secure such scheme the commission shall have the authority to require the modification of any project and of the plans and specifications of the project works before approval."

While the commission is not given authority to grant rights of way for irrigation uses only, or to authorize the erection in navigable waters of structures solely for navigation use, it is apparent from the provisions of the statute that it has the authority and the duty to give consideration to both of these uses in so far as they affect power development within its jurisdiction. If there are possible or projected navigation or irrigation developments which will affect possible or projected power developments on any stream, it is the duty of the commission to investigate these uses and their effects, and if upon such investigation it finds that a certain scheme of composite development is best adapted to the utilization of the stream for all purposes, it is competent for the commission to issue permits or licenses for power developments in conformity with such finding; in fact, not otherwise can the power projects which it approves meet

the requirements of the law that they "shall be such as in the judgment of the commssion will be best adapted to a comprehensive scheme of improvement and utilization."

In accordance with this view the commission at its meeting of January 24, 1921, directed "that whenever a power project affects a stream which is suitable for purposes other than power development a joint study by the several Government or State agencies be conducted whenever practicable in order that licenses should not be granted without taking into consideration all interests affected thereby." In pursuance of this action two major investigations have been undertaken, one of the Deschutes River in Oregon, report of which was published in 1922, and one of the upper Columbia River, the subject of the attached report.

For the Deschutes River investigation a board of engineers was selected, consisting of Col. J. B. Cavanaugh, Corps of Engineers, representing the commission, Mr. D. C. Henny, of the Reclamation Service, and Mr. Fred F. Henshaw of the United States Geological Survey. A representative of the State of Oregon was unable to participate. Since the problems involved in the Columbia River investigation were similar to those on the Deschutes, the same Federal members were requested to serve on the Columbia River investigations, and in addition the States of Idaho, Montana, and Washington were requested to name representatives on the board. The Columbia River board, as thus constituted, consisted of the following:

J. B. Cavanaugh, colonel, Corps of Engineers, chairman.

D. C. Henny, consulting engineer, United States Reclamation Service.

Fred F. Henshaw, district engineer, United States Geological Survey.

W. G. Swendsen, commissioner, department of reclamation, Idaho.

C. S. Heidel, state engineer, Montana.

Marvin Chase, supervisor of hydraulics, Washington.

The board was instructed to make a study of the Columbia River from Flathead Lake to the mouth of the Snake River; to report on the character and extent of present and prospective uses of the river for navigation, irrigation, and power, with a discussion of the relative merits of each and of their relation to each other; and to outline a program of development that would harmonize the conflicting uses in such manner as to secure, in the long run, the greatest combined benefit from all. The river along a part of its course passes through the Dominion of Canada. There is also a treaty with Great Britain relating to navigation on the river. The board was, therefore, instructed to give consideration to these matters in its report. Since

the irrigation of a large area of land in the State of Washington, known as the Columbia Basin project, and the method of securing water for and supplying it to this project would be likely to affect in very considerable degree the ultimate power possibilities of the Columbia River, the board was instructed to secure and review all available data and to report its opinion as to the effect which the two possible alternate methods of water supply—that is, by gravity or by pumping—would have upon the development of power on the river.

After nine months of investigation the board has submitted a report which is concurred in by the three Federal members and by the representatives of Idaho and Montana. The representative of Washington concurs in the conclusions and recommendations of the other members of the board except with respect to the Columbia Basin project, holding that the board was without authority to inquire into the relation to power development of alternate methods of irrigation development. It is sufficient to reply that the board was acting in this respect under instructions, that the subject of the inquiry was clearly within the authority of the commission, and that a report which omitted this particular study would be of little value to the commission. In so far as the representative of the State of Washington has from the data available reached conclusions different from those reached by the five other members of the board, the majority and minority reports hereto attached may be permitted to speak for themselves.

Very truly, yours,

O. C. MERRILL,
Executive Secretary.

The CHAIRMAN OF THE FEDERAL POWER COMMISSION.

PORTLAND, OREG., *June 30, 1922.*

The board of engineers appointed to make a general study of the upper Columbia River beginning at Flathead Lake, with a view to outlining a scheme of development best suited to the needs of power, irrigation, and navigation on the Columbia, submits herewith its report.

Marvin Chase, supervisor of hydraulics of the State of Washington, and a member of the Columbia River board, concurs in the conclusions and recommendations of the board except as to the consideration of the Columbia Basin project in said report. He dissents from the treatment and conclusions of the majority of the board regarding that project, and has filed a dissenting minority report with exhibits,

dealing particularly with the Columbia Basin project, which is submitted herewith.

Respectfully submitted.

J. B. CAVANAUGH,
Colonel, Corps of Engineers, Chairman.
D. C. HENNY,
Consulting Engineer, U. S. Reclamation Service.
FRED F. HENSHAW,
District Engineer, U. S. Geological Survey.
C. S. HEIDEL,
State Engineer, Montana.
W. G. SWENDSEN,
Commissioner, Department of Reclamation, Idaho.
MARVIN CHASE,
Supervisor of Hydraulics, State of Washington.

The FEDERAL POWER COMMISSION,
(Through Executive Secretary),
Washington, D. C.

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REPORT ON THE USES OF THE UPPER COLUMBIA RIVER.

I. INTRODUCTION, CONCLUSIONS, AND RECOMMENDATIONS.

INTRODUCTION.

1. This board has been appointed, at the instance of the Federal Power Commission, to make a general study of the upper Columbia River, beginning at Flathead Lake, with a view to outlining a scheme of development best suited to the needs of power, irrigation, and navigation on the Columbia, in order that the action of the commission in passing upon permits and licenses for power development may be in accordance with some well-defined policy.

2. The personnel of the board includes not only representatives of the departments of the Federal Government most vitally concerned, but also representatives of the three States within which the waters of the upper Columbia will be used.

3. In its consideration the board has used various data taken from governmental records and from State reports and other public documents, and studies based upon these data have been prepared by the members of the board and by the district engineer at Seattle.

4. The first meeting of the board was held at Portland, Oreg., September 12, 1921. Since that time the work of investigation has been steadily in progress by the board and its members and meetings were held from time to time in Portland, Spokane, and Seattle.

5. During September 20 to 24, 1921, inclusive, the board made a field inspection of the route selected by the Columbia Basin Commission for the gravity diversion canal of the Columbia Basin irrigation project, of the dam sites under investigation on the Columbia River for irrigation pumping, and of the lands to be watered. The board was assisted in this inspection by officials of the State of Washington connected with the project.

6. From September 25 to 27, 1921, inclusive, inspection was made of Flathead Lake, with a view to its use as a storage reservoir, and of the proposed power-dam sites on the Flathead and Clark Fork Rivers.

7. On May 7, 1922, a committee of the board made an inspection of the proposed dam site at Kettle Falls, on the Columbia River, and on May 8 and 9 of Pend Oreille and Priest Lakes.

8. On February 14, 1922, conference was had at Seattle with Mr. R. G. Swan, district chief engineer, dominion water power branch,

Department of the Interior, Canada, and the reciprocal effect of the uses of waters of the Columbia in the United States and Canada, respectively, was fully discussed.

9. On March 28 and 29, 1922, a public hearing was given at Spokane, Wash., to all interests deeming themselves affected by the disposition of the waters of the upper Columbia and its tributaries.

10. A description of the upper Columbia River, covering the important physical characteristics of its watershed, is given in Chapter II.

11. The investigation and report are required to cover the following principal points:

(*a*) A general résumé of power, irrigation, and other possible uses to which the water may be devoted.

(*b*) A program of development that will harmonize the interrelated uses in such manner as to secure the greatest benefit from them all.

(*c*) A policy to be followed by the United States and the States of Montana, Idaho, and Washington in using, reserving, or disposing of public lands, waters, reservoirs, and power sites.

12. The situation with respect to navigation on the upper Columbia system and its future possibilities and requirements are given in a statement prepared by the district engineer at Seattle, in charge of the navigable waters affected, which is submitted herewith as Appendix A.

13. The present situation with reference to the use of water for power and irrigation and possible prospective uses for irrigation are set forth in statements prepared by the members of the board from the three States affected and submitted herewith as Appendices B, C, and D.

14. All these matters were considered and discussed in detail by the board, and their interrelation is set forth in Chapter III of this report. In this detailed presentation programs of development and the policy to be followed by the Federal and State Governments concerned are discussed.

15. In this presentation discussion has not been extended to those tributary streams, such as the Spokane and the Kootenai, upon which conditions are practically fixed or which will be without material effect upon future changes in the discharge of the main river.

CONCLUSIONS.

16. The conclusions arrived at, which embody a general scheme of development considered by the board as best suited to the needs of power, irrigation, and navigation on the Columbia, are stated in Chapter III, but are repeated here for convenient reference, as follows:

(*a*) Freedom should be given to fullest irrigation expansion in Montana, Idaho, and Washington, and no rights should be allowed to accrue to the lower interests which would legalize limitation of or interference with irrigation above.

(*b*) The Columbia Basin project is the most important single item to be considered in the uses to be made of Columbia River water above the mouth of Snake River.

(*c*) The Columbia Basin project can be irrigated by gravity from the Clark Fork at Albany Falls or by pumping from the Columbia River at Grand Coulee.

(*d*) The Columbia Basin gravity project can be adequately supplied by the aid of storage in Pend Oreille and Priest Lakes in Idaho, conditioned upon maintenance of natural flow from Flathead Lake when needed.

(*e*) The Columbia Basin project can be supplied with practically no shortage without the aid of storage, with a dam at Grand Coulee about 156 feet high above low water.

(*f*) Information upon which to base a final decision between a gravity and a pumped supply for a Columbia Basin irrigation project is not complete and should be completed. Any decision should take into account the effect upon potential power.

(*g*) Pending such decision no permanent rights of storage should be granted in Pend Oreille and Priest Lakes.

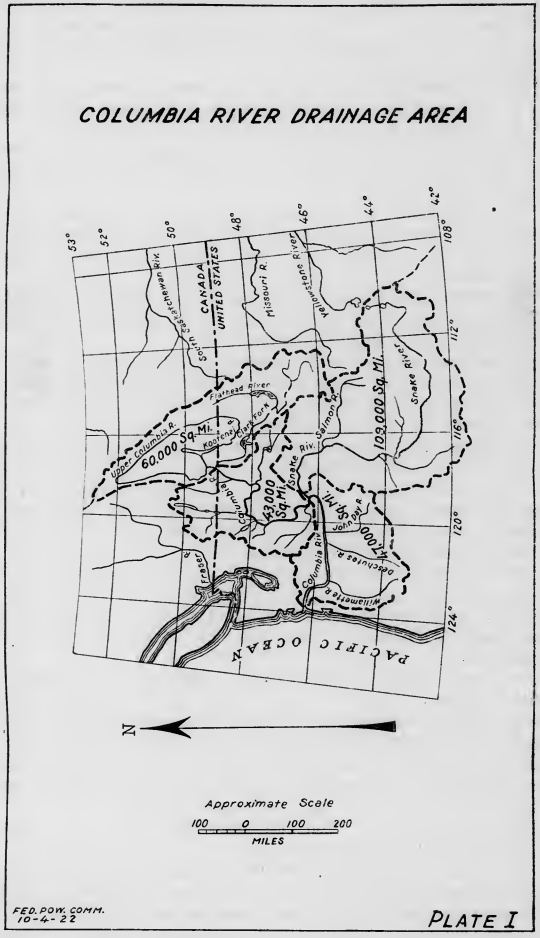
(*h*) If ultimately the decision is in favor of a Columbia Basin gravity project, storage rights in Pend Oreille and Priest Lakes should be granted to such project, but should be limited to storage of inflow in excess of 7,000 second-feet.

(*i*) If ultimately the decision is in favor of a Columbia Basin pumping project, storage rights in Pend Oreille and Priest Lakes should be granted to the joint interests of power on the lower Clark Fork and the Columbia River, subject to limitations contained in section (*a*).

(*j*) Storage rights in Flathead Lake should be granted to Flathead power interests, subject to fullest development found practicable after complete investigation. Prior to such development, rights may be advantageously granted to power interests on Clark Fork subject to conditions protecting ultimate control for Flathead power and natural flow release when needed for the protection of the Columbia Basin project if built on the gravity plan.

(*k*) Storage control at Flathead, Pend Oreille, and Priest Lakes should be under impartial supervision.

(*l*) A permit to develop power at the Grand Coulee site or at any point on the Columbia River as far downstream as the Foster Creek site should not be granted to power interests until it is known that such site will not be needed by the Columbia Basin project. In case



the Columbia Basin project shall require a power site for irrigation and power on this stretch of the Columbia River, a permit should be granted to it after the best location and height of dam shall have been determined from the standpoint of the project and the public interest.

RECOMMENDATIONS.

17. If a policy of action in harmony with the above conclusions be adopted as a basis for action on power applications, it is believed that the general public interest will be served to the fullest extent; that all feasible irrigation development dependent on the waters of the upper Columbia River will be safeguarded; that irrigation and water power development will be coordinated; and that interference with river navigation by dams can if necessary be converted into decided improvement by the construction of locks, and that interference with lake navigation can be corrected by dredging; and it is recommended that the conclusions set forth in section 16 be approved; that the right to flood public and State lands marginal to Flathead, Pend Oreille, and Priest Lakes be reserved; and that copies of this report be furnished to the governors of Montana, Idaho, and Washington.

II. DESCRIPTION OF BASIN.

AREA AND EXTENT.

1. Columbia River drains an area of about 259,000 square miles, divided among political divisions as follows:

	Square miles.	Per cent.
Washington	48,000	18.5
Idaho	81,389	31.4
Montana	25,000	9.7
Nevada	5,280	2.0
Wyoming	5,270	2.0
Oregon	55,370	21.4
Total United States	220,300	85.0
British Columbia	38,700	15.0

The drainage basin area is shown on Plate 1.

2. The principal tributaries of the Columbia are the Clark Fork, rising in Montana and flowing through Idaho and Washington to its mouth in British Columbia, and Snake River, rising in Yellowstone Park and traversing Wyoming, Idaho, Oregon, and Washington to its confluence with the Columbia at Pasco, Wash.

The drainage area of the Columbia may be segregated by stream basins as follows:

	Square miles.	Per cent.
Columbia River above Clark Fork	34,000	13.1
Clark Fork	26,000	10.0
Columbia River at international boundary	60,000	23.1
Middle area, boundary to Snake River	43,000	16.7
Snake River	109,000	42.1
Columbia River below Snake River	212,000	81.9
Lower area, Snake to mouth	47,000	18.1
Total	259,000	100.0

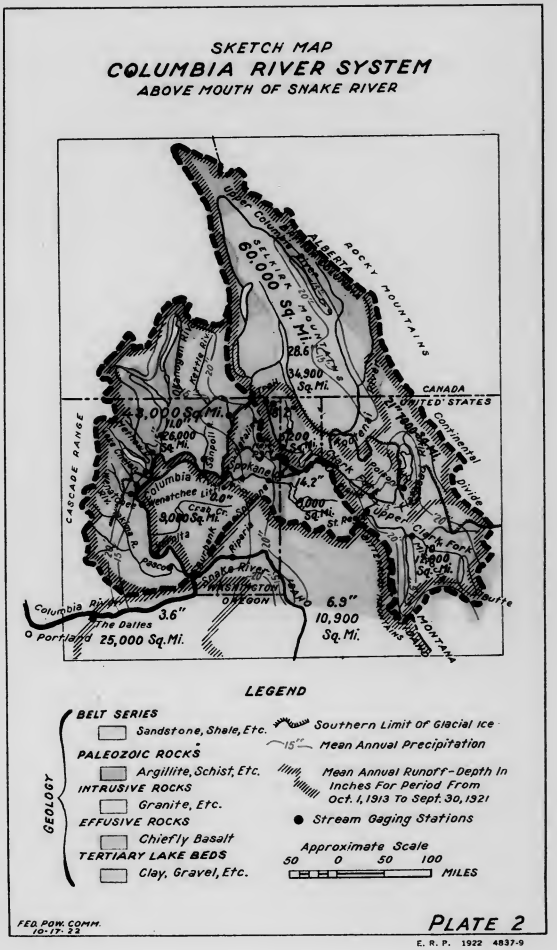
The drainage basin of Columbia River above the Snake is shown on Plate 2.

3. The run-off of the Columbia may be compared to that of other large rivers as follows:

River.	Point.	Drainage area.	Maximum flood (thousands of second-feet).	Mean run-off.		Period of record.
				Millions of acre-feet.	Depth in inches over drainage area.	
		Sq. miles.				
Clark Fork	Newport, Wash	24,200	200	19.4	15.0	1903–1921
Columbia	Trail, British Columbia	34,000	306	53.5	29.5	1913–1921
Columbia	Vernita, Wash	95,500	520	92.2	18.7	1913–1921
Columbia	The Dalles, Oreg	237,000	1,160	151	12.0	1878–1920
Frazer	Hope, British Columbia	83,600	340	69	15.1	1912–1920
Colorado	Yuma, Ariz	242,000	240	17.2	1.3	1902–1917
Missouri	St. Charles, Mo	527,000	600	72.4	2.6	(1)
Ohio	Paducah, Ky	202,000	1,400	217	20.2	(1)
St. Lawrence	Ogdensburg, N. Y	383,000	330	182	8.9	(1)
Yukon	Eagle, Alaska	122,000	254	53	8.2	1911–1913
Nile	Assuan, Egypt	1,267,000	353	84	1.6	(1)
Danube	Mouth	300,000	.....	171	10.7	(2)

[1] See Water Supply Paper 347, p. 77.
[2] Encyclopædia Britannica. Other results taken from published records.

4. From this it appears that Columbia River at The Dalles has a run-off somewhat less than that of the Danube, St. Lawrence, and Ohio Rivers, the latter with a somewhat smaller drainage basin. The Columbia River at Vernita, above the Snake, is slightly larger than either the Frazer, Missouri, or Nile, the latter two with much larger basins, while at Trail, just above Clark Fork, it carries as large a flow as the Yukon at Eagle, which has a catchment area nearly four times as large. Clark Fork at Newport has a slightly larger mean discharge than Colorado River at its mouth, just below the Yuma gauging station.



INTENTIONAL SECOND EXPOSURE

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Columbia	Vernita, Wash.	95,500	520	97.2	18.7	1913–1921
Columbia	The Dalles, Oreg.	237,000	1,160	151	12.0	1878–1920
Frazer	Hope, British Columbia	85,600	380	69	15.1	1912–1920
Colorado	Yuma, Ariz.	242,000	240	17.2	1.3	1902–1917
Missouri	St. Charles, Mo.	527,000	600	72.4	2.6	(1)
Ohio	Paducah, Ky.	202,000	1,400	217	20.2	(1)
St. Lawrence	Ogdensburg, N. Y.	303,000	330	182	8.9	(1)
Yukon	Eagle, Alaska	122,000	254	53	8.2	1911–1913
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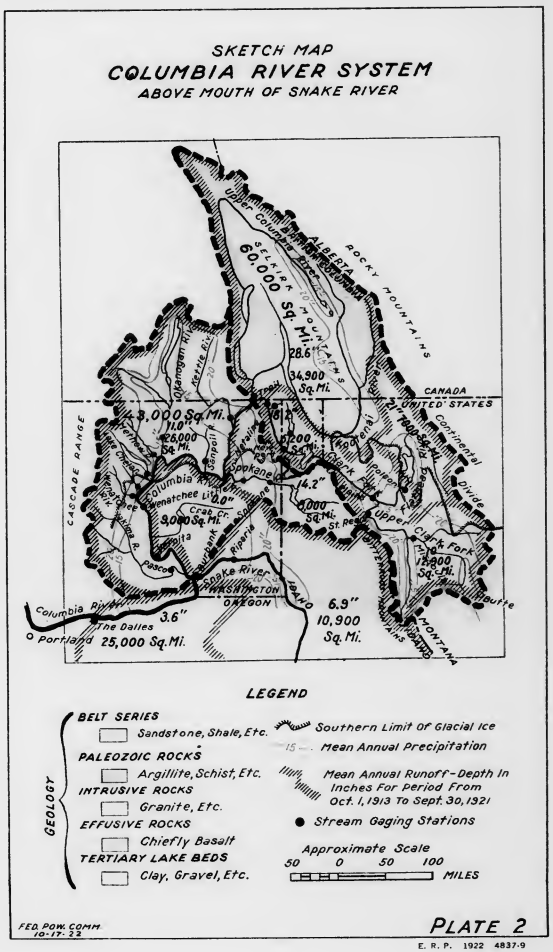

TOPOGRAPHY.

5. The great cordilleran mountain system of North America is composed of several parallel ranges, the whole covering a broad belt extending from the Pacific Ocean to the western limit of the Great Plains. The genesis of these mountain ranges is closely related to great folds and faults, which are in general parallel to the coast line. Successive cycles of uplift and erosion have produced in certain areas a topography characterized by flat-topped ridges or accordant summit levels and innumerable narrow, deep, steep-sided valleys.

6. The drainage basin of upper Columbia River embraces a portion of the great intermontane watershed which lies between the Rocky Mountains and the Cascade Range. The Rocky Mountains, which form the divide between this and the Atlantic watersheds, reach elevations ranging from 8,000 to 12,000 feet, the highest peaks lying in Canada. near the northern limit of the Columbia River drainage.

7. West of the main Rocky Mountain divide and roughly parallel to it are several mountain ranges that become successively lower until they merge into a broad plateau. Between the ranges lie long, narrow valleys, the most extensive of which, known as the Rocky Mountain Trench, lies at the foot of the main range and extends from about latitude 46° at the head of Bitterroot River, in Montana, to a point far to the north of the Columbia watershed.

8. This topography has controlled the courses of the streams and the location of most of the important water-power sites. The larger rivers, not only the Columbia and its tributaries but tributaries of the Frazer and McKenzie, rise in the Rocky Mountain Trench and follow it northward or southward for long distances with no great fall. Eventually, however, the streams break through the adjoining mountain range into the next valley to the west. Upon reaching this valley the Columbia and Kootenai reverse their direction and nearly double back on their former courses. The greatest fall of the streams occurs in the gorges through the mountains, and the reservoir sites lie in the intermontane valleys. Thus the upper Columbia, rising in the Rocky Mountain Trench at about latitude 50° north, flows thence northwestward for about 170 miles to the great bend near Canoe River. Here it plunges over many rapids and emerges into the valley in which lie the Arrow Lakes and through which its course is somewhat east of south.

9. Though differing in detail, the courses of Flathead River and Clark Fork in general have characteristics similar to the upper Columbia. Flathead River rises in the Rocky Mountain Trench and flows southeastward to Flathead Lake. At the outlet of the lake it flows southwestward at right angles to the general trend of the mountain

ranges. This course is marked by valuable power sites. The Flathead below Dixon, Mont., and the Clark Fork below Paradise have a moderate average fall, but favorable power sites exist, as, for example, at Thompson Falls and Cabinet Gorge, where the stream crosses beds of quartzite.

10. Below Lake Pend Oreille, Clark Fork passes through a less elevated region than its upper basin in Idaho and Montana, and its northwestward course to Metaline, Wash., is marked by no considerable fall. From Metaline to its mouth, however, where it cuts across the Bonnington Range, it falls more than 600 feet in less than 20 miles.

11. South of the international boundary the channel of Columbia River lies in a wide valley several hundred feet below the surrounding mountains and plateaus. Its course takes a southerly direction for nearly a hundred miles, to the mouth of Spokane River. Near this point it turns abruptly westward, making what is known as the "Big Bend." Farther on it turns southward and then southeastward, and thus almost surrounds on three sides a region known as the Big Bend country. The fall of the Columbia through the State of Washington is heavy for so large a river, amounting to more than 1,000 feet in 400 miles. Concentrated fall occurs at many points, which in some places afford favorable power sites, as at Kettle Falls and Priest Rapids. At Kettle Falls the fall is due to a reef of hard quartzite extending across the stream bed. At Priest Rapids the anticline that elevated the rocks to form Saddle Mountains is an obstacle which the river has not been able entirely to remove. At Pasco the Columbia receives its largest tributary, the Snake, and a few miles beyond makes its final turn westward toward the sea.

12. The lands proposed to be irrigated by the Columbia Basin project are within the area partly surrounded by the Columbia in its course from the mouth of the Spokane to Pasco, commonly known as the Big Bend country.

In general this area is a plain that slopes gently southwestward from an elevation of about 2,300 feet west of Spokane to about 500 feet near Pasco.

GEOLOGY.

13. The geology of a river basin is of interest in connection with a study of water utilization to the extent that the geologic formation may modify the run-off, affect its storage, or influence the fertility and quality of the soil. For instance, existence of a country rock of porous or fractured lava may render the creation and use of storage reservoirs of such uncertain success as to defeat the development of projects dependent upon them. Glacial action may produce storage basins; in fact, most of the lakes available for water storage have been created or greatly modified by ice action. The moraines which dam their outlets are commonly found to be more or less impervious to water owing to their content of clay, but on the other hand, a moraine may be highly pervious.

14. The areal geology of the region considered herein is shown in broadly generalized fashion on Plate 2, which was chiefly compiled from the geologic map of North America (map accompanying U. S. Geological Survey Professional Paper 71), and maps accompanying U. S. Geological Survey Bulletin 677 and Bulletin No. 20 of the Washington Geological Survey.

15. The rocks that underlie the drainage area of upper Columbia River naturally fall into two groups that differ greatly in age and contrast strongly in their general features. The older group comprises rocks that range in age from pre-Cambrian to early Tertiary. They consist chiefly of sandstone, shales, and limestones, the metamorphic equivalents of these such as quartzite, argillite, schist, and hornstone, and granitic rocks of intrusive origin.

16. Much the greater part of the area being considered is occupied by the rocks mentioned above. A great thickness of sandstone, shales, and limestones known as the Belt series underlie a large area (Pl. 2) along the Rocky Mountains extending from southern Montana almost to the extreme northern point reached by Columbia River in Canada. Quartzites, argillites, schists, and limestones, thought to be mostly paleozoic in age, occupy much of the area in Washington and Idaho north of Spokane. Large areas of intrusive rocks appear north of the Canadian line and in northeastern Washington north of Columbia and Spokane Rivers. Less extensive outcrops of similar rocks are found in several other places, one of which is the northern part of the Grand Coulee.

17. Except perhaps the granite, the rocks of the older group have been severely folded and faulted, as a result of which they are commonly traversed by seams, shearing planes, and similar structures. Under the influence of weathering these structures become more or less open and cause the mass to be disrupted into fragments of various sizes that commonly form a talus stream or other form of surface mantle. The weathered zone, however, is usually thin. Beneath it the rock is firm, and capable of supporting engineering structures of any weight and of holding water in storage without serious leakage.

18. After the rocks of the older group had been deformed as mentioned in the preceding paragraph they were elevated and carved by erosion into a rugged mountainous land. Later on parts of the land became depressed and in these low areas the rocks of the younger group were deposited.

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19. The rocks of the younger group occupy practically all of the region in eastern Washington known as the Columbia Basin and the Big Bend country, and a vast area to the south in Idaho and Oregon. In addition small patches of them are found here and there in northeastern Washington and western Montana.

20. Most of the area occupied by these rocks is underlain by the Columbia River or Yakima basalt, a formation made up of several separate layers or flows of lava superimposed one above the other. Over considerable areas these layers are almost horizontal, remaining in practically the same altitude they assumed when they came to rest as layers of fluid lava. In other areas, as the Yakima region, they have been moderately bent and broken. In the region known as the Columbia Basin they have acquired a very gentle dip to the southwest.

The basalt is a rather hard rock that varies from dense to porous or cellular in texture and usually affords a strong foundation for dams or other works, but its different layers are commonly broken by so many open joints or other fractures that water passes through it rather freely for long distances. Therefore storage basins in the basalt, such as the proposed lake in the valley of Latah Creek would probably be subject to serious leakage.

21. Sediments generally referred to as Tertiary lake beds form a rather small part of the younger group. They are interbedded with the basalt, lie beneath it in places, and in places cover its surface. Consequently they have undergone about the same amount of deformation as the basalt. The most extensive area of the lake beds is in the neighborhood of Pasco (Pl. 2) near which place they form the conspicuous feature known as white bluffs. The layers that are interbedded with the basalt, or that lie beneath it, are exposed here and there only in the walls of canyons or coulees.

22. Many of the Tertiary lake beds are fine textured dense shales or clays practically impermeable to water as shown by the fact that springs commonly rise along their outcrops. Other beds are porous and all are inclined to be rather soft or loosely consolidated and not likely to afford safe foundations for works of any considerable size.

23. Deposits of glacial origin form the remaining part of the younger group. Over most of the area north of the latitude of Spokane glacial drift forms a patchy mantle that ranges from nothing to several hundred feet in thickness, but its average depth is probably no more than a few feet. In the Big Bend and Columbia Basin region the glacial deposits are practically confined to the valleys and coulees, rather extensive areas of them occurring in the valley of Latah Creek and in the neighborhood of Moses Lake.

Most of the glacial deposits, including the materials classified as moraine, till, and outwash, are gravels. Exceptions to this are certain light-colored silts that form terraces along Columbia River above Nespelem and in the northern part of the Grand Coulee. Some of them, like the moraine at the outlet of Flathead Lake, make good dams because of the abundant clay which they contain. In general, however, the glacial deposits, particularly those in the Big Bend and Columbia Basin region, are open textured and easily permeable to water.

24. Glaciation has greatly modified the drainage of the region. It is safe to say that practically all the lakes in the region are the result of glacial action, which has either hollowed out rock basins or dammed valleys with drift. When at its maximum the ice completely blocked the valley of Columbia River and turned its flow into the coulees that cross the Big Bend country. After the melting and retreat of the glacier most of the streams regained their former valleys though in places their courses were changed somewhat. In some of these places, Spokane Valley for example, the streams are marked by falls due to the fact that reefs of hard rock were uncovered while the streams were engaged in cutting their new channels. The approximate southern limit of glacial ice is shown on the geologic map (Pl. 2).

PRECIPITATION.

25. The mean annual precipitation in the Columbia River Basin varies according to location from 6 to over 100 inches. It generally increases with altitude, and under otherwise similar conditions, decreases with increased distance from the sea. Isohyetals have been derived from records of available precipitation stations and certain supplemental information. They are in the nature of the case approximate, and they are especially uncertain in the higher mountains through insufficient number of rainfall stations. Plate 2 has been prepared showing areas with mean annual precipitation of less than 15 inches and more than 20 inches.

26. It may be broadly stated that where the precipitation exceeds 20 inches, the country is forested and mostly mountainous, and that where it is less than 15 inches, the country is arid, while the intervening areas have a climate merging from humid to arid.

27. It will be noted that the areas with low rainfall lie in two broad belts, one comprising east central Washington, and extending northward up the Okanogan Valley into British Columbia, the other lying in the intermontane valley of Montana and British Columbia. It is within the arid areas that the greater part of the land is situated having a topography sufficiently smooth to permit of agricultural

development. The remainder of the agricultural land is largely embraced in the wheat belt of eastern Washington and northern Idaho, and extends into the areas having over 20 inches of precipitation.

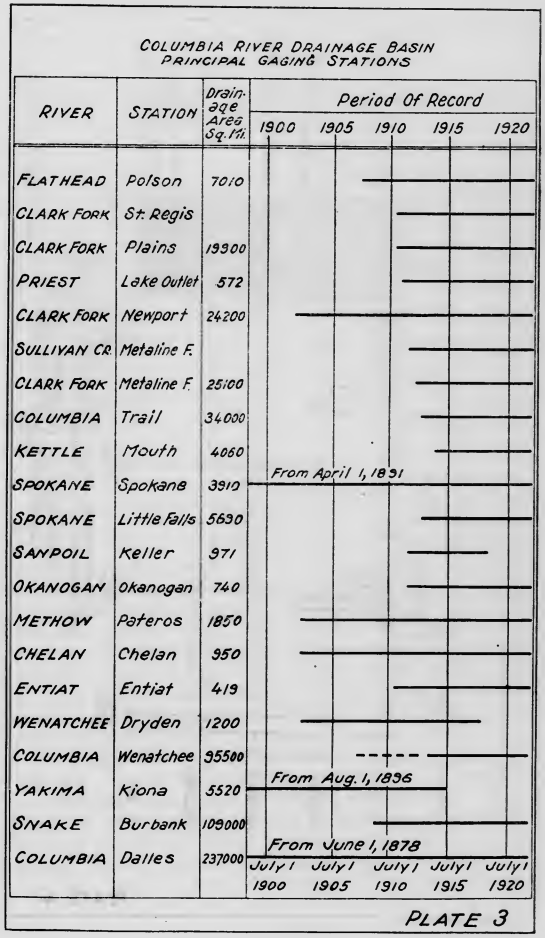
STREAM FLOW.

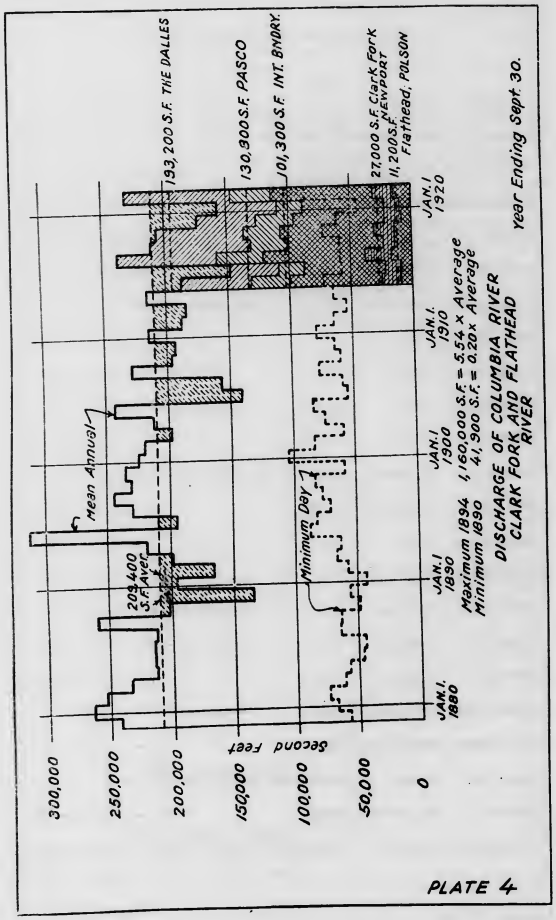
28. Plate 2 indicates the principal river gauging stations maintained by the United States Geological Survey. Plate 3 shows the period of time during which these stations have been maintained.

29. The station with longest record is at The Dalles, Oreg., at which point the flow of 91 per cent of the entire Columbia Basin has been measured since 1878. This report is not directly concerned with the flow at The Dalles, since it contains the inflow from Snake River and other streams coming in below Pasco. The record, however, is of great value for comparative purposes in view of the much shorter time for which records are available of stream flow above Pasco, which at some essential points are continuous or complete only after 1913, and therefore comprise only a period of 8 years.

30. The mean annual flow at The Dalles for the period 1878 to 1921 is shown on Plate 4, which also indicates the minimum flow for each year. The average flow for the entire period is 209,400 second-feet. Plate 4 further shows for the recent 8-year period the flow above Snake River, at the international boundary, the flow in Clark Fork at Newport, and of Flathead River at Polson.

31. During this 8-year period, the average flow past The Dalles has been 193,200 second-feet, 7½ per cent less than the average for the entire period 1878 to 1921. In a general way this indicates that most conclusions as to stream flow based on the flow during the last 8 years may be considered as conservative, although the diagram also indicates that the lowest mean annual flow occurred in the climatic year October 1, 1888, to September 30, 1889, and the minimum flow occurred in the year 1890. A study of the plate shows in addition that the recent 8 years did not contain an extended period of 3 years of relatively low flow such as occurred from October 1, 1888, to October 1, 1891.





32. The mean annual flow at various points along the river from Flathead Lake to the mouth of Columbia River, for the period October 1, 1913, to October 1, 1921, together with drainage areas and run-off figures, is shown on the following table:

Mean annual flow at points from the outlet of Flathead Lake to mouth of Columbia River for the period October 1, 1913, to October 1, 1921.

	Flow.	Intermediate inflow.	Drainage area.	Intermediate area.	Run-off.	
					Second-feet per square mile.	Depth in inches.
	Sec.-ft.	*Sec.-ft.*	*Sq. miles.*	*Sq. miles.*		
Flathead River, Polson	11,200		7,200		1.55	21.0
Intermediate stretch		9,400		12,700	0.74	10.0
Clark Fork, Plains	20,600		19,900			
Intermediate stretch		7,000		5,200	1.34	18.2
Clark Fork, Metaline Falls	27,600		25,100			
Intermediate stretch		73,700		34,900	2.11	28.6
Columbia River, International boundary	101,300		60,000			
Intermediate stretch:						
From West		21,100		26,000	0.81	11.0
From East		8,400		[1] 8,000	1.05	14.2
Columbia River, Pasco	130,800		103,000			
Intermediate stretch		55,700		109,000	0.51	6.9
Columbia River, below Snake	186,500		212,000			
Intermediate stretch		6,700		25,000	0.27	3.6
Columbia River, The Dalles	193,200		237,200		0.81	11.0
Intermediate stretch		[2] 66,800		22,000	[2] 3.04	41.0
Columbia River, mouth	260,000		259,000		1.00	13.6

[1] Area of 9,000 square miles below mouth of Spokane River yields no run-off.
[2] Estimated.

33. The last column of this table gives the depth of run-off over various parts of the general drainage area which figures are also shown on Plate 2. It will be noted that the most prolific portion of the area, yielding nearly 29 inches in depth, is in British Columbia, drained by the upper Columbia and Kootenai Rivers. This portion of the basin is believed to give a higher run-off per square mile than any other drainage basin of equal size on the Continent of North America. The next area in the Columbia River watershed in order of high run-off is that of Flathead River above Polson from which the yield was 21 inches. From the above figures the depth of run-off shades down to 3.6 inches principally from the central Oregon country below the mouth of the Snake River.

34. A comparison between depth of run-off and precipitation, Plate 2, largely explains the great difference in depth of run-off. There are other important factors, however, to be taken into consideration, especially consumption of water by irrigation, which in the territory between the Cascade Range and the Columbia River, in central Oregon, and more particularly in the Snake River drainage area, tends seriously to deplete the run-off measured at the gauging stations.

STORAGE RESERVOIRS.

35. The basin of upper Columbia River, having been subjected to extensive orographic movements and to general glaciation abounds in lakes nearly all of which present possibilities of water storage. Only three of these are considered in the present report.

36. *Flathead Lake.*—This lake lies in western Montana at an elevation of nearly 2,900 feet and covers an area of 120,000 acres or 188 square miles. It is supplied and drained by Flathead River, which being larger than Clark Fork, at their junction might quite properly be considered the main stream. The drainage area above the gauging station, immediately below the outlet of the lake is 7,010 square miles and the average run-off for 1908–1921 was 8,330,000 acre-feet, equivalent to 22.3 inches over the basin.

37. Flathead Lake has a fairly steep shore line except at its upper end, where the upper Flathead has built up a large delta. A considerable area of this delta is flooded at ordinary high water.

38. Flathead Lake was evidently drained in former geologic time by a channel through Big Draw, a depression extending westward from Big Arm; this channel was blocked by a great mass of glacial detritus and the river sought its present outlet through the rocky gorge below Polson. No misgivings need be entertained as to the probable tightness of the reservoir basin, especially as the water need not be held at as high a level as it has often reached under natural conditions.

39. *Lake Pend Oreille.*—Lake Pend Oreille occupies a deep depression in the panhandle of northern Idaho, and is broadly crescent shaped. The northern part of it may be considered a widening and deepening of the Clark Fork Channel, but the greater portion of the area is embraced in a southern projection which occupies a north-south valley. For purposes of this report the lake may be considered as extending down to Albany Falls, with a length along its curved axis of 65 miles and covering an area of 86,000 acres at low water, and 98,000 acres at the high-water stage of 1913 or 1916.

40. Lake Pend Oreille has the topographic character of a drowned valley with several ramifications. Its shores are constituted in part by cliffs of rock that plunge as precipitously beneath the water as they rise above it; in part by more gentle rock slopes or shelving beaches of shingle. The south shore of the eastern arm is precipitous, but much of the western portion of the lake is bordered by gravel beaches. The meadow lands at the head of the lake have all the characteristics of a true delta, which the river overflows when swollen by melting snow. The outlet of the lake is between rocky banks and at Albany Falls the river crosses a dike of hard rock, affording satisfactory foundation for a controlling dam.

41. *Priest Lake.*—Priest Lake forms an enlargement of Priest River, which discharges into Clark Fork immediately below Lake Pend Oreille and about 5 miles above the proposed dam at Albany Falls. It has an area of about 24,000 acres at low water. The drainage area above the outlet of the lake is 572 square miles and the average run-off 862,000 acre-feet, equivalent to 29 inches in depth over the basin. Priest Lake presents an irregular shore line, but the banks are fairly steep along most of its border and the area subject to flooding by a raise of water surface is not large. Priest River leaves the lake over a bed of bowlders and compacted material between banks of sand and gravel. The fall is about 30 feet in the first 2 miles to a point where the river passes through a narrow defile, where rock is exposed on both sides to a considerable height. A dam could easily be built to the desired height, either at the gorge or at the outlet.

III. INTERRELATION OF INTERESTS IN THE USE OF COLUMBIA RIVER WATER.

1. The natural flow of the Columbia River and its tributaries and the manner in which it may be regulated by storage, affect the following interests:

(*a*) Marginal reservoir site ownership.
(*b*) Flood control.
(*c*) Navigation.
(*d*) Irrigation.
(*e*) Power.
(*f*) Relations with Canada.

2. These interests in their development are likely to interfere with each other. It is the main object of this report to analyze the claims which have been or may be advanced by each and to recommend to the Federal Power Commission the principles which might underlie its decisions in the consideration of applications for power permits.

3. At the public hearings held by the board in Spokane on March 28 and 29, 1922, most of the above subjects were discussed by interested parties, and their statements were placed on file. All these subjects, whether represented at the hearings or not, must receive full consideration.

MARGINAL RESERVOIR SITE OWNERSHIP.

4. Large reservoir sites exist on the headwaters of the Columbia River, all consisting of natural lakes which can be effectively and economically controlled by the construction of dams and outlet works. The most prominent sites in the United States are Flathead Lake, Pend Oreille Lake, and Priest Lake, all in the drainage basin of the Clark Fork. Minor reservoir sites in the United States have been

ignored, as they are of insufficient capacity materially to affect the general problem of river regulation.

5. Interests needing storage will desire to use storage facilities to their utmost extent compatible with reasonable cost and controllable inflow. This desire conflicts with the interests of owners around the lakes, who wish to have a distinct limit placed upon the extent to which storage control shall be exercised.

6. There are large lakes in British Columbia such as Arrow and Kootenai Lakes, which might be utilized as a means of river regulation. Their importance has been fully recognized and most friendly cooperation has been received by this board in the consideration of this question from dominion and provincial authorities. The board was advised that no definite plans have been formulated for the utilization of storage in these lakes, that their use for power in British Columbia must be carefully limited so as not to interfere unduly with plans of land reclamation, that future irrigation expansion and consequent stream depletion are rather limited, and that the effect of full use of storage and final irrigation expansion in British Columbia upon the Columbia River south of the international boundary can not at the present time be foretold. Information at hand indicates that the effect will be relatively small and so far as it may be felt is likely to be beneficial in increasing the low water flow. In the absence of definite data no estimate of this effect has been attempted.

7. *Flathead Lake.*—This lake is located on the Flathead River in Montana and has an area at low water of 120,000 acres. The natural fluctuations of the lake as observed on the Polson gauge have been between elevation 97 (in 1894) and 78.7 (in 1919 and 1920), covering a range of 18.3 feet and giving a storage capacity of 2,300,000 acre-feet. The highest water in recent years stood at 92.7 (in 1916).

8. At the public hearings in Spokane, commercial and landed interests at Flathead Lake registered their objections to lake storage with ordinary high water above certain elevations not specifically mentioned, by reason of extensive destruction of valuable farm lands and apprehended spoliation of scenic beauty. This subject was dealt with in greater detail at previous hearings on January 26 and 27, 1922, at Polson and Kalispell, Mont., before Col. Edward H. Schulz on behalf of the Federal Power Commission, the records of which were made available to this board.

9. In addition to private and commercial interests, the Federal Government in its control over public and Indian lands and over navigation is a party to the question of storage, and any final decision is therefore clearly beyond the scope of this report. It has, however, been deemed necessary to assume, for the purpose of concrete consideration of the general problem, definite figures for ultimate permissible storage capacity, in reasonable harmony with public interest and not likely to meet with strenuous objection from local communities or private interests affected, or from the State of Montana.

10. The Columbia Basin commission of the State of Washington made a study of the situation at Flathead Lake, and in its report of 1920 the conclusion is presented that storage would not cause undue injury or excessive cost up to 93 feet, Polson gauge. With normal low water assumed at gauge height 80.3, this would give a range of control of nearly 13 feet and a storage capacity of 1,600,000 acre-feet.

11. The maintenance of water at elevation 93 during the summer, at times extending into the fall, will cause the submersion of certain areas of land, mainly at the north end of the lake, and will interfere with proper drainage of higher lands. Injury to individuals is to be compensated, and measures can be taken to improve drainage. Very valuable and economical storage could easily be had if higher lake control could be acquired, but local injury would thereby increase rapidly.

12. From information at hand, it appears that the community interests north of the lake, even assuming that just damages are paid and effective measures are taken to assist drainage, will strenuously oppose a normal high water elevation of 93, the more so as it must be understood that during exceptional climatic conditions such as occurred in 1894, extreme stages may be experienced as high as under natural conditions in the past.

13. Objections were raised to lake storage because of destruction of scenic beauty. The lake frequently rises above gauge height 88. Consequently a margin will be affected by storage to 93 of only 5 feet in vertical height. In general, the slopes are steep, and, if tree growth is cleared from the submerged margin, no material injury to scenic beauty need be feared, the more so as the lake will generally be kept at full height until the beginning of August and not drop below 90 until the middle of October.

14. The Indian Service has interests in the lake, and has constructed a tunnel intended for the development of power for irrigation pumping. The conditions which on this as well as other accounts may be imposed by the various departments of the Federal Government, including the War Department as regards navigation, will have to be met, but these are not likely to prove unduly burdensome.

15. In subsequent studies it has been tentatively assumed that the lake can be developed to yield controllable storage to the extent of 1,600,000 acre-feet, or 94,000 acre-feet more than was figured by the Columbia Basin commission. The ultimate Flathead Lake storage can not at the present time be fixed, as the expense which may be involved in damages and in enlargement of the outlet channel will

have to be determined at the time the storage works are needed and because this expense must be compared with the benefit derived.

16. It may be stated nevertheless that the flood of 1916 which rose to gauge 92.7 caused land submergence between the north end of the lake and Kalispell such as may well seem seriously objectionable to the local community as a level for normal high water in the lake under storage control, and that a regulated high-water level will probably have to be adopted materially lower and possibly as low as 90 on the Polson gauge.

17. Objection will also be made if the lake be lowered below past low-water levels. Such lowering, however, would take place at rare intervals, and then only in February and March, and if proper measures are insured for prevention of damage to navigation it is not seen that this objection should receive very serious consideration.

18. Maintenance of required outflow at low-lake stages may involve large expense in channel excavation. It has not, however, been possible for this board to enter into this subject in detail, and in any event the amount of controllable storage must largely be left, under limitations which may be imposed, to the interests who are to pay for such storage.

19. A storage of 1,600,000 acre-feet may be had between the following gauge heights:

(*a*) High water, 93 feet; low water, 80.3 feet.

(*b*) High water, 92 feet; low water, 79.2 feet.

(*c*) High water, 91 feet; low water, 78.1 feet.

(*d*) High water, 90 feet; low water, 77 feet.

The above as well as all other Flathead Lake elevations herein mentioned refer to the Polson gauge. The information at hand is to the effect that 0 of this gauge is 2,803 feet above sea level.

20. The Kalispell interests will probably be satisfied with condition (*d*), and possibly condition (*c*) can be fairly considered. It may further be desirable at the time of extreme emergencies, such as occur but seldom and then only as stated in winter, to permit a temporary further lowering of the lake below ordinary low water, subject always to the beneficiaries complying with requirements as to navigation. It is upon this basis of a controllable content of 1,600,000 acre-feet and a small winter draft below low water at times of great emergency that the hydrographic studies of this board have been based.

21. Should it prove ultimately uneconomical or for valid reasons impermissible to obtain such full control, the effect will be mainly felt by the interests directly dependent on Flathead storage and will be progressively smaller as regards development on the Clark Fork and the Columbia River as such interests depend more upon inflow and storage from other sources and less upon Flathead storage regulation.

22. *Pend Oreille Lake.*—This lake is situated on the Clark Fork in northern Idaho and has a low-water area of 86,000 acres. The lake has fluctuated between elevations 2,079.3 (in 1894) and 2,050.1 (in 1919), giving a range of 29.2 feet and a natural storage capacity of 2,716,000 acre-feet. In recent years the highest water level has been 2,071.7 (in 1916), affording storage for nearly two million acre-feet.

23. The Columbia Basin commission proposed control between elevations 2,051 and 2,065, a range of 14 feet providing a storage capacity as figured by the commission of 1,180,000 acre-feet. Land damage in the case of this lake does not increase nearly as rapidly with further height increase as in the case of Flathead Lake. With an increase of 5 feet to elevation 2,070, however, about 4 miles of the Great Northern Railway between Albany Falls and Sand Point may have to be raised in order to maintain a freeboard of 5 feet.

24. At the public hearing at Spokane statements in response to questions of the board indicated that no serious community damage would result from establishing normal high water at 2,070. Since that time a communication was received from the Sandpoint Chamber of Commerce, dated April 3, 1922, in which it is declared to be the sense of the people of Bonner County that high water for storage purposes should not be fixed higher than elevation 2,061. Considering, however, that the lake under present conditions, except in extremely low years, rises above this elevation every year, and, for instance, stood 7 feet higher during the entire month of June, 1917, and reached an elevation over 10 feet higher, viz, 2,071.7, in July, 1916, compliance with this request of the Sandpoint Chamber of Commerce is practically equivalent to abandonment of the use of this valuable asset for storage purposes.

25. It is judged from data now available, from examination and conference on May 8, 1922, between the Chamber of Commerce of Sandpoint and a committee of the board, that a range on Pend Oreille Lake for storage purposes of between 2,050.7 and 2,070 will be found a reasonable use of the lake, and one which will neither necessitate the payment of very high damages nor cause undue hardship to local communities. Such range will give a storage capacity of 1,750,000 acre-feet.

26. It should be understood that in unusual years water may rise and fall to more extreme elevations, as in the case of Flathead storage; no higher or lower, however, than would obtain under natural conditions.

27. *Priest Lake.*—Priest Lake is also situated in the northern part of Idaho. It is fed and drained by Priest River, a tributary of the Clark Fork, coming in below Pend Oreille Lake, but above the dam proposed at Albany Falls to control this lake. It commands a small drainage area (572 square miles) but a relatively high run-off amount-

ing to an annual average of over 800,000 acre-feet. Its area at low water is about 24,000 acres.

28. The lake lies in the Kaniksu National Forest. The land on the west side of the lake is nearly all in public ownership. The land on the east side was mostly transferred to the State of Idaho, which in turn sold the standing timber on part of the area, subject to certain annual payments and a time limit for removal.

29. The Columbia Basin commission did not consider in its report the use of Priest Lake for irrigation storage. Its position low on the stream, its favorable run-off, and the fact that no extensive improvements have been made around the lake, and in so far as known no great area of agricultural lands would be flooded, limit any objection to its use to protests from those who use the adjacent grounds for cottages, camping, and recreation and to timber interests. As to the amount of timber which may be flooded and which is privately owned, this board has no definite information. It is quite certain, however, that ample time will be available to cut this timber before the lake is actually raised, which fact will tend to minimize the damage.

30. Storage in the lake, conditioned on clearing flooded timberlands, should be regarded as in the best interest of the public, in view of the great value of storage. It is therefore assumed for the purpose of this report that the lake can be controlled between elevations 2,434 and 2,457 with storage capacity of 600,000 acre-feet, which is sufficient to fairly utilize the inflow. Further investigation may indicate that the desirable range of stage may be obtained in part more advantageously by lowering the outlet of the lake, thus minimizing the damage of submergence at the higher level.

31. It is of course understood that any damage to property, either in personal, corporate, or other ownership growing out of changes in lake levels in Priest or Pend Oreille Lakes, will be satisfied by the beneficiaries of storage.

32. *Total permissible storage.*—The assumptions as to permissible storage in the three reservoirs above enumerated are summarized as follows:

		Capacity.
Flathead Reservoir	acre-feet	1,600,000
Pend Oreille Reservoir	do	1,750,000
Priest Lake Reservoir	do	600,000
Total		3,950,000

FLOOD CONTROL.

33. The flood-control problem on the Columbia River system refers to the inundation of lands marginal to the large lakes through which the main river and its tributaries flow and of valley lands along the river near and below Portland, and also to danger to railroads in the narrow and deep valley through which the river flows for the remainder of the distance.

34. The total area of land subject to flood inundation consists altogether of only a few hundred thousand acres. So far as this land is marginal to lakes in the upper reaches of the stream the use of these lakes for storage will not affect appreciably their present condition and any injury to higher lands due to storage must be paid for by the interests on behalf of which storage is provided or must be compensated for by improved drainage.

35. As regards the lands near and below Portland, there are about 150,000 acres subject to river overflow, of which less than one-third have been reclaimed by diking and are generally well protected against damage from ordinary floods. Such a flood, however, as that of 1894, which is the largest on record since 1858, and peaked at The Dalles with a flow of 1,160,000 second-feet, would overtop the dikes of 90 per cent of the lands so far reclaimed and would therefore cause serious crop and property damage.

36. All new railroad construction since 1894 has taken cognizance of the 1894 flood levels and is not likely to suffer materially by a recurrence of such flood.

37. A small area in the city of Portland was inundated through high levels in the Columbia River affecting the Willamette River flowing through that city, and did no lasting serious damage.

38. On the whole, the flood problem of the Columbia River is of small consequence as compared with that on other large streams with vast alluvial plains and large industrial areas subject to inundation.

39. Little if any benefit could be derived from flood control through storage. This is due to the fact that the location of storage reservoirs is about 1,000 miles distant from the seat of the principal flood danger and that, being located near the headwaters, the flood inflow below amounts to more than 75 per cent of the total run-off.

40. The permissible storage capacity of these reservoirs is also small relative to the remaining 25 per cent of run-off. For instance, total permissible storage on the Clark Fork may not reach 4,000,000 acre-feet. The flood flow of 1916, which is the largest of which records are at hand on the Clark Fork, shows a total run-off during June and July of 12,000,000 acre-feet.

41. The run-off into the reservoirs was therefore in that year more than three times and in 1894 may have been four times the permissible storage, from which it is evident that the reservoirs, even if used solely for flood control, would probably have been entirely filled before the occurrence of the flood peak and could not have had any appreciable effect on flood conditions nearly a thousand miles below.

42. In so far as natural storage may have ameliorated flood conditions in the past, practically the same benefit would result in future after storage reservoirs are built, because the lakes would fill and reach extreme flood levels about in the same manner and at the same time as under natural conditions.

43. The subject of utilization of available storage possibilities for flood control may therefore be dismissed from consideration.

NAVIGATION.

44. Navigation of the river above Pasco is at present but slightly developed as shown by the report of Colonel Schulz (Appendix A), and will at all times be hampered, so far as not affected by pondage at power or storage dams, by the steep river gradients and be limited in commercial importance especially above Bridgeport, Wash., by the depth of the channel below the surrounding country, by the relatively small area of valley lands immediately adjacent to the river, and by the existence of a well developed and expanding system of railroads.

45. The river is partly used for driving logs, notably parts of the Clark Fork, but the use of storage for maintenance of flow during the low-water season is notoriously wasteful unless produced incidentally in connection with irrigation or power development as its main object. It is important, however, that at some dams, especially at the dams controlling storage in Pend Oreille and Priest Lakes, facilities be provided for the passing of logs. Likewise, in the construction of all dams whether for storage, power, or diversion the question of the necessity of locks will have to be carefully considered for construction either simultaneously with the dam or later when practical use can be made of such locks in connection with river improvement for navigation above and below. The subject of lock construction on the main river in the United States is in the hands of the War and State Departments, and as to division of cost in the hands of Congress. This report need take cognizance of this subject only as it may affect cost of dams and relations with Canada.

46. Navigation on the lakes will not necessarily be interfered with by the use of lakes for storage, as on the whole storage control will tend to increase navigation depth at critical periods and if lakes are drawn down to lower elevations than those which have prevailed in the past, proper provision can be exacted for the protection of navigation.

IRRIGATION.

47. Superiority of the rights of irrigation over those of power as regards diversion from the natural stream flow has been conceded by all the representatives of power interests who have appeared

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before this board, and indeed is in accord with the trend of court decisions and the administrative river control in Idaho and Washington, and also with the general public interest. There is at present in the river from Flathead Lake down to Pasco a flow greatly in excess of any actual diversions and so far as the Clark Fork below Albany Falls and the Columbia River below the international boundary are concerned this condition will always exist.

48. There is large potential irrigation expansion in all these States traversed by the Columbia River system above Pasco, as is shown in Appendices B, C, and D. No protest has been made to this board by any interests with which resultant stream depletion might interfere, except as regards the one large proposed irrigation diversion which might materially affect stream flow, viz, that proposed for the irrigation of the Columbia Basin.

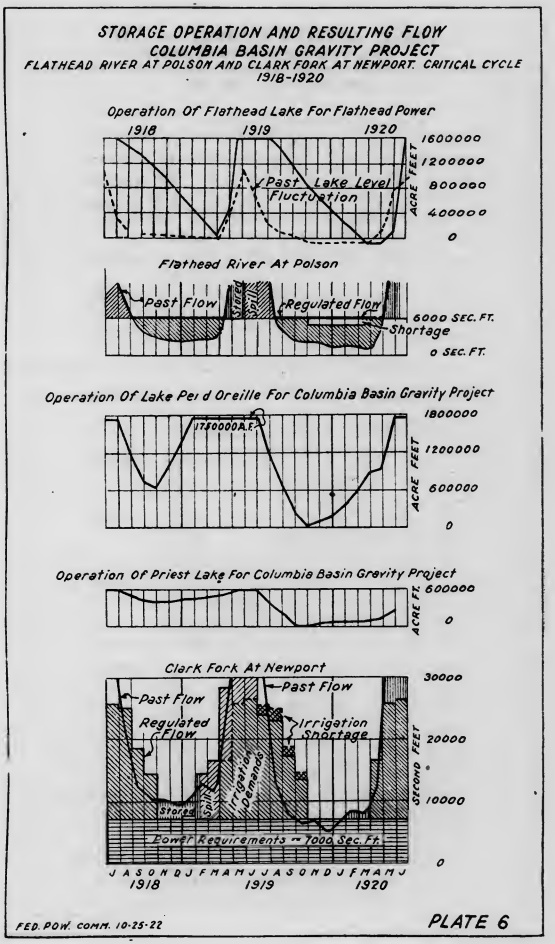
49. Even in this case, the objection is aimed not at the right to withdraw the required water from the stream, which is not questioned in view of the large benefits which would ultimately be derived from such irrigation, but is directed solely to the location of the diversion point which might be selected.

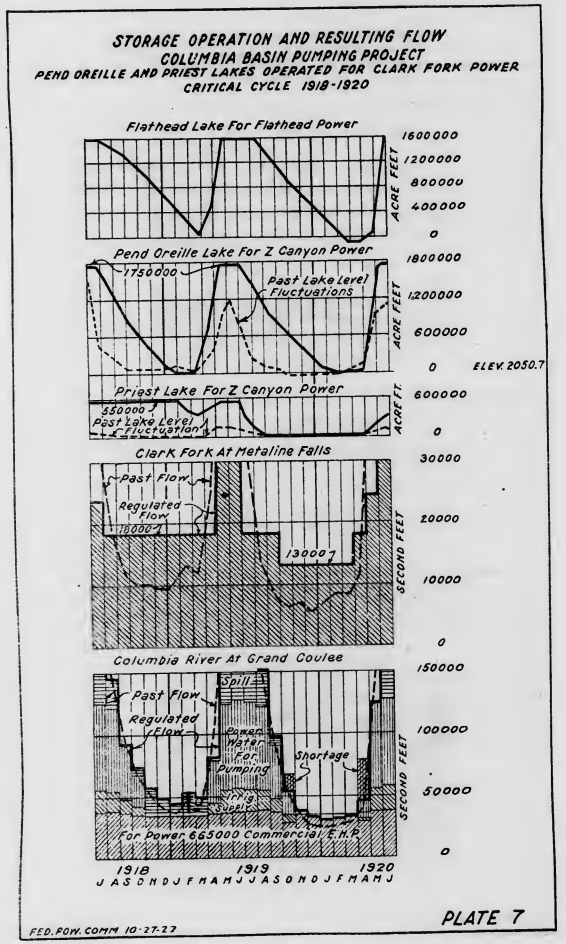
50. Two points of diversion have been proposed, one on the Clark Fork just above Albany Falls, by gravity, and one on the Columbia River near the head of Grand Coulee, by pumping (see Pl. 5). The selection between these two points will have a grave effect upon power possibilities, especially on the Clark Fork below Albany Falls, both in Washington and British Columbia. Power interests, while conceding paramount rights to the Columbia Basin project, hold that they should not be injured unnecessarily.

51. This feature of the conflict runs not only to the diversion of the natural streamflow, but is closely interwoven with the important subject of the use of storage for stream regulation necessary alike for Columbia Basin irrigation if by gravity and for the full development of power resources.

52. The board has studied both the Columbia Basin gravity project with diversion at Albany Falls on the Clark Fork, and the pumping project with a power dam near the head of Grand Coulee. Constructional and engineering problems for either project, although difficult and complex, can be satisfactorily solved.

53. For present purposes it has not been deemed necessary or practicable to decide on the immediate feasibility of the project. Such a decision would involve far greater study of essential elements than this board has been able to make, notably of the prospective rates of land settlement, and would also require more dependable estimates of cost of both the gravity and the pumping plan. It seems certain, however, that sooner or later with growing population and demands for farm products and with improved methods of





construction, a proper balance will be reached between total cost and value created. The economic possibilities of a Columbia Basin project are so great, as compared with any other use which can be made of the water, that no claims to water for power purposes should be permitted to grow up which will interfere with their realization, so far as any action by the Federal Power Commission is concerned. The object to be held in view, therefore, is to facilitate Columbia Basin reclamation without unnecessarily injuring other interests.

54. The future requirements of the Columbia Basin project were studied first on the basis of the published report of 1920 of the Columbia Basin commission. The State has, however, amended its figures as to estimated seasonal irrigation requirements (see Appendix D), comparative figures being shown in the following tabulation, based on an irrigation project containing 1,753,000 acres:

Gross diversion requirements.

Month.	Columbia Basin Commission, 1920.		Present estimate presented by the State.		Difference (acre-feet).
	Second-feet.	Acre-feet.	Second-feet.	Acre-feet.	
April	8,000	476,000	9,400	561,000	+85,000
May	15,100	928,000	18,700	1,152,000	+224,000
June	16,700	995,000	19,400	1,152,000	+157,000
July	18,900	1,161,000	18,700	1,152,000	−9,000
August	20,600	1,270,000	17,700	1,090,000	−180,000
September	14,400	858,000	11,500	685,000	−167,000
October	8,600	530,000	7,100	436,000	−94,000
Total		6,218,000		6,228,000	

55. The requirements after July 1 and consequently during the usual season of storage release, aggregate 450,000 acre-feet less as now suggested by the State than the amount estimated in the commission's report. Adoption of this new schedule implies a reduction to the above extent of the estimated needs of storage.

56. An independent estimate made by some of the members of this board would provide an average of 36 inches instead of an average of 33 inches net on the land. On the other hand, it takes cognizance of the great possibilities of using return flow both by gravity and low lift pumping and of the possibility that some acreage farthest away from the source of water supply may be more cheaply served from nearer sources. Such estimate leads to demands after July 1 comparable to the reduced figures after that date now submitted by the State.

57. Remaining differences of consequence refer to a reduction of earlier irrigation demands rather than an increase, but as the earlier period is one of usually abundant stream flow, these differences may be

for the present disregarded, and hydrographic studies have therefore been based on the new State schedule.

58. In these studies deductions have been made from past river flow which may result in future from complete irrigation expansion in Montana and Idaho, as estimated by the respective State representatives, and as shown in Appendices B and C. The total storage required to satisfy the demands of the Columbia Basin gravity project are on this basis estimated as follows:

	I	II	III
	Acre-feet.	*Acre-feet.*	*Acre-feet.*
1903	649,000	1,065,000	1,118,000
1904	1,584,000	1,451,000	1,830,000
1905	2,195,000	2,389,000	2,603,000
1906	2,185,000	2,083,000	2,561,000
1907	160,000	225,000	349,000
1908	1,098,000	1,011,000	1,415,000
1909	965,000	1,132,000	1,388,000
1910	1,914,000	2,091,000	2,310,000
1911	1,226,000	1,211,000	1,461,000
1912	649,000	822,000	823,000
1913	846,000	828,000	1,113,000
1914	1,568,000	1,389,000	1,695,000
1915	1,124,000	1,162,000	1,362,000
1916	21,000	50,000	78,000
1917	1,046,000	463,000	1,508,000
1918	1,505,000	1,389,000	1,678,000
1919	2,787,000	2,706,000	3,360,000
1920	1,080,000	1,165,000	1,348,000
1921	1,593,000	1,515,000	2,051,000

59. The estimates in columns I and II are predicated on Pend Oreille Lake storage, 1,750,000 acre-feet, and Priest Lake storage, 600,000 acre-feet being used to satisfy the demands of the Columbia Basin gravity project. Column I is based on outflow conditions from Flathead Lake as they exist naturally, and column II on future conditions if Flathead Lake storage of 1,600,000 acre-feet is controlled for the benefit of Flathead River power to be referred to in detail hereafter. Column III shows the storage figured to be required by the Columbia Basin gravity project in case it depends solely on Flathead and Pend Oreille storage, as proposed by the commission, both being handled for the direct benefit of the project. Maintenance of 7,000 second-feet flow past Newport is assumed in columns II and III, which are predicated on use of Flathead Lake.

60. It will be seen that 1919 is the critical year. With Flathead Lake yielding natural storage as in the past, the required storage is 2,797,000 acre-feet, as shown in column I, and with the lake controlled for power as under column II, this storage is 2,706,000 acre-feet. If the storage capacity in the lower lakes is 2,350,000 acre-feet, as was assumed, there would be a shortage of 356,000 acre-feet, with Flathead controlled for power. This shortage is equivalent to about 10 per cent of the seasonal needs after July 1, and being the only appreciable shortage in the entire cycle of 19 years, it is of no serious consequence. Reservoir and flow conditions for the critical cycle are shown on Plate 6.

61. In these studies allowance has been made for stream depletion due to future irrigation expansion in Idaho and Montana, and some minor corrections for stream flow have been introduced.

62. Thus it is found (see column III, section 58) that in 1919 there would have been required, if Pend Oreille and Flathead Lakes were given over to the use of the Columbia Basin gravity project as proposed by the commission, a storage of 3,360,000 acre-feet, which is greater than the 2,686,000 acre-feet provided by the commission, but is about equal to the amount assumed as permissible by this board, to wit, 1,600,000 acre-feet for Flathead and 1,750,000 acre-feet for Pend Oreille.

63. The effect upon the Columbia Basin gravity project of assigning Pend Oreille and Priest Lakes to the use of this project and Flathead Lake to the use of power in Montana and Idaho, would be to leave in a period of nineteen years a relatively unimportant irrigation shortage during a single year. This leads to the conclusion that such project does not need direct control over Flathead Lake. The effect upon power of this plan is discussed later. The method of storage regulation together with power demands on the Flathead River, irrigation demands at Albany Falls, and power and irrigation shortages are shown for the critical cycle 1918–1920 in Plate 6.

64. The above refers exclusively to the gravity method of supplying Columbia Basin. The Columbia River approaches closely to the northern edge of the irrigable lands at the point where it passes the head of Grand Coulee. At this point rock exposures on both sides of the river indicate that a suitable site might exist for a high masonry dam which would afford power for pumping river water from the raised dam pond into the Coulee.

65. The total lift from river to Coulee is about 630 feet, and a dam 200 feet high would leave a remaining height of 430 feet as pump lift. Such height of lift will at first sight seem impracticable for the purpose of irrigation and certain to result in excessive cost. This impression would result logically from the fact that, under conditions compelling the use of fuel engines or transmitted power from commercial plants, lifts of 75 and 100 feet have been regarded as the usual economical limit, although plants lifting water over 200 feet under these conditions are in successful operation in California.

66. It was realized, however, that with abundant seasonal power available at the pumping plant, with the large volume of water to be pumped and the consequent great size of units which could be employed, unusual conditions exist which would at least justify

a study. Such study was made in 1920 by the Columbia Basin commission.

67. The depth of bedrock across the valley was at that time unknown. The commission made an estimate of cost which showed an acre cost of a pumping project 5 per cent higher than of a gravity project. A Federal board of review was of the opinion that upon further investigation a pumped supply might be found both cheaper and more free from danger of interruption than a gravity supply, and suggested for the benefit of the State of Washington that for the purpose of taking stock of its natural resources it appropriate $50,000 principally to ascertain the position and character of bedrock at Grand Coulee, and partly to make additional examinations and studies to permit a reasonable comparison of the two methods of project supply.

68. Part of such study has been made for the State by Mr. W. T. Batcheller, and the Grand Coulee Dam foundation has been explored by 14 diamond-drill borings. These borings have shown that an excellent quality of granite continues unbroken from exposure on the left to exposure on the right side of the river valley, and that its elevation under the river is at much less depth than was assumed by the commission. Rock was found at 60 feet below low water in the river on an almost level plane 2,500 feet wide with only one marked depression of small extent, this plane connecting with granite rock slopes, rising at the rate of 1 vertical to 2.34 horizontal on the right bank, and of 1 vertical to 1.40 horizontal on the left bank. The rock is overlaid with clay which forms the river bed, and on this clay at the foot of the mountain slopes rests a mass of talus.

69. Conditions for dam construction may be regarded as unusually favorable by reason of excellent foundation, character of material overlying bedrock, and openness of site, which render river diversion during construction relatively easy.

70. The studies made for the State by Mr. Batcheller indicate clearly the practicability of power and pumping machinery of the large sizes required with resultant acre cost figures which, after further study and revision may compare favorably with those of the gravity project, even if they are to include some large items necessary to insure safety at the Grand Coulee Dam; and also the cost of locks which, according to preliminary estimates of Colonel Schulz, may amount to about $1.50 per acre. (See Appendix A.) These studies also indicate the low cost at which all year commercial power can be produced at the dam and that, with a growing power market, the cost of irrigation can be reduced materially through the gradual development and sale of this power.

71. The commission found in 1920, that while 1,753,000 acres could be irrigated under a gravity canal, only 1,403,000 acres could be covered by a Grand Coulee pump canal. Mr. Batcheller gave consideration to repumping to additional lands and studied pumping projects with total areas up to 1,857,000 acres. One of the alternatives thus considered is for the same area as that of the gravity project, viz, 1,753,000 acres, in which case 80 per cent of the land would come under a primary pump canal and 20 per cent under a high canal with 200 feet secondary lift.[1] The power for secondary pumping is to be transmitted from the Grand Coulee Dam over a relatively short power line.

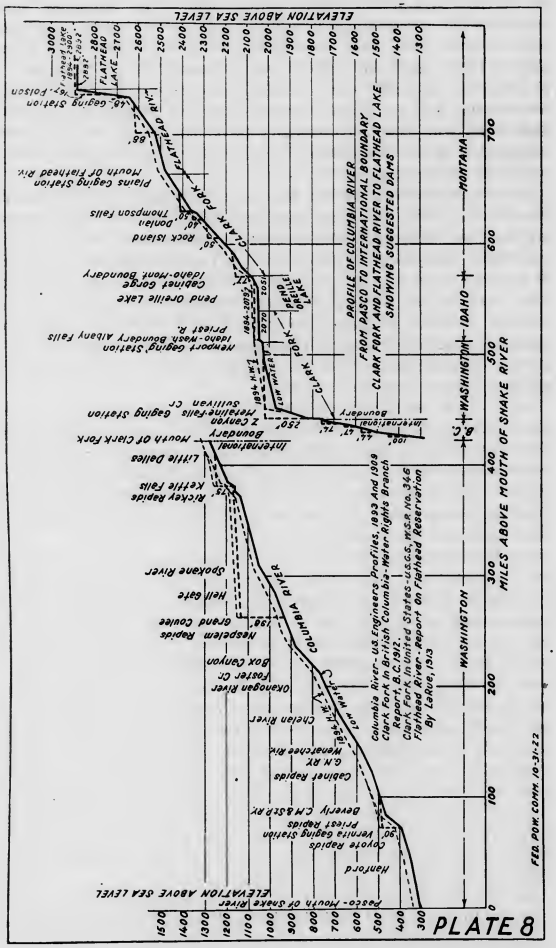
72. Mr. Batcheller used such data as were available in the Columbia Basin survey office to make a paper location of the secondary pumping plant and high canal, and has based his estimates thereon. It has since been contended that such canal is not feasible and that most of the land under it is not irrigable. As regards the first contention, this board can not make any definite statement in the absence of a survey. So far as its inspection in the field is concerned, no greater obstacles were noted to a high line pump canal than exist along the gravity canal in this section of the project. Only a survey can give positive information on this point.

73. As to the quality of the land, if projects of equal size are considered one supplied by pumping and the other by gravity, the 350,000 acres of land in regard to which doubt was expressed as to its quality overlaps about 300,000 acres of land listed as irrigable in the gravity project. Of the character of the remaining 50,000 acres no positive knowledge is at hand and there is a possibility of this area being cut down upon careful classification.

74. So far as extent of project area is concerned which can be covered by gravity and by pumping, there is no positive evidence that the pumping project will be smaller in area, and as it will make low cost power available for pumping to areas of excellent land lying above the primary pump canals in various parts of the project, it may in fact be larger. Only additional studies and further surveys can determine this question. As to cost, Mr. Batcheller has submitted acre-cost figures for numerous alternatives. The bulk of the project area and distribution system is identical and was estimated by him at the same cost as was figured in the commission's 1920 report. As to the remainder, it was unavoidable that large uncertainties should also exist. So far as his cost figures show, the acre cost of a pumping project is found to be lower than that of a gravity project, which is in harmony with the findings of the commission's report when due allowance is made for the more favorable conditions at the Grand Coulee Dam site than those assumed in the cost estimates.

75. The flow required in the Columbia River consists of the amount of water to be diverted for irrigation and several times this amount

[1] Note by the Commission: A relift above the secondary lift would probably be required in order to cover the same area as the gravity project.


ELEVATION ABOVE SEA LEVEL
PROFILE OF COLUMBIA RIVER FROM BASCO TO INTERNATIONAL BOUNDARY CLARK FORK AND FLATHEAD RIVER TO FLATHEAD LAKE SHOWING SUGGESTED DAMS
MONTANA
IDAHO
WASHINGTON
MILES ABOVE MOUTH OF SNAKE RIVER
Columbia River - U.S. Engineers' Profiles, 1883 And 1909
Clark Fork In British Columbia - Water-Rights Branch Report, B.C. 1912.
Clark Fork In United States - U.S.G.S. W.S.P. no. 346
Flathead River - Report on Flathead Reservation By Leland, 1913
FED. POW. COMM. 10-31-13
PLATE 8

needed for producing power for primary and secondary pumping. The total clearly depends upon the height of the Columbia River Dam, which governs both the power available and the primary pump lift.

76. The height of the dam may be figured on the basis of furnishing just sufficient power during the irrigation season to do the needed pumping, either with or without the aid of storage. In the latter case the height would be 156 feet above extreme low water (938), with unimportant shortage in an occasional cold April, and in the former case it would be considerably lower.

77. The river profile (see Pl. 8) shows that the dam may be built to raise the water about 200 feet and possibly more without interfering with the proposed development at Kettle Falls, and that if built to a permanent height of only 156 feet, a waste of power resources will undoubtedly ensue which it is important to avoid. This matter will be dealt with in detail under the head of "Power."

78. Mr. Batcheller, in calculating relative cost of dam and of pumping machinery, found that there was a distinct tendency of aggregate costs to balance, and that the increase in the cost of a higher dam will be largely offset by a reduction in the cost of machinery. If the Federal Power Commission should exact the condition of full height of dam in granting a permit for a Grand Coulee Dam, it is believed this requirement could not be seriously questioned by the proponents of the Columbia Basin pumping project.

79. Studies made by this board of Columbia River flow required at Grand Coulee Dam, besides being based on a project area the same as that for the gravity project, also assumed an identical seasonal supply schedule. For a dam with overflow crest at elevation 1,138, giving effective heads on turbines normally ranging from 198 feet in winter to 182 feet in summer, the required river flow was determined as follows:

1	2	3	4	5	6	7	8	9	10	11
			Turbine pumping power.						Lowest flow since Oct. 1,1913.	
	Irrigation supply.	Gross pumping head.	Primary at 77.7 per cent efficiency.	Secondary at 72.2 per cent efficiency.	Total.	Head on turbines.	Water for power for pumping at 90 per cent efficiency.	Total required flow for irrigation.	Amount.	Year.
	1,000 sec.-ft.	Feet.	1,000 Horsepower.			Feet.	1,000 sec.-ft.	1,000 sec.-ft.	1,000 sec.-ft.	
April	9.4	432	593	59	652	192	35.2	42.6	46.2	1920
May	18.8	432	1,188	118	1,306	186	68.8	87.6	116.3	1920
June	19.4	432	1,225	122	1,347	184	71.4	90.8	214.4	1920
July	18.8	432	1,188	118	1,306	183	69.7	88.5	227.1	1919
August	17.8	432	1,124	112	1,236	182	66.4	84.2	142.2	1914
September	11.5	432	727	72	799	186	42.0	53.5	85.2	1921
October	7.1	432	448	45	493	191	25.2	32.3	53.5	1919

80. In column 10 of the above table is given the minimum flow for each month since October 1, 1913, amended for full Montana and Idaho irrigation expansion and for Flathead Lake power control. It will be noted that there is at all times sufficient water in the stream to give a 100 per cent irrigation supply.

81. The cycle 1913–1921 is a relatively low one, as regards run-off. Comparison at The Dalles shows that the average flow for the period 1879–1921 was 209,400 second-feet, while that for the period 1913–1921 was 193,200 second-feet, or about 8 per cent less. In order to obtain some further perspective view on sufficiency of flow at Grand Coulee, an estimate was made of such flow covering the entire cycle, by proportioning from The Dalles flow for the earlier period. The results for the lowest years prior to 1913 may be compared in the table below, with Grand Coulee irrigation requirements.

[1,000 second-feet unit.]

	Required at Grand Coulee for irrigation.	Estimated flow at Grand Coulee.		
		1889	1905	1906
April	42.6	59	52	78
May	87.6	136	113	154
June	90.8	168	230	220
July	88.5	142	194	221
August	84.2	124	146	140
September	53.5	79	79	93
October	32.3	59	69	63

82. The above table shows that for the earlier, as well as the late years of the cycle 1879–1921, there was always an ample flow at Grand Coulee for the irrigation power and diversion requirements of a Columbia Basin pumping project. It should be stated in this connection, that in the calculation efficiency figures of machinery were used as given in the Batcheller studies, based upon weeks of personal conference with the engineers of one of the largest and ablest manufacturers of such machinery in the United States.

83. It is apparent from the above that a Columbia Basin project can be supplied from the Columbia River at Grand Coulee without the aid of any storage, even after all stream depletion to be expected from upper irrigation, as well as Flathead storage control for Flathead power, are called for.

84. It is further evident that the summer excess flow, in conjunction with the winter flow, will afford large possibilities for the development of all-year commercial power, and that this power can be materially increased by the aid of storage. If a large demand for such power should develop from industrial centers, warranting the construction of power trunk lines, or from industries established near the site dependent on abundance of low cost power, it could be satisfied by the progressive installation of generating machinery.

85. The development of such power may be coordinated with the settlement of irrigable lands and the expense of storage need not be incurred until the combined demands of both exceed the unregulated river flow.

86. The amount of power which can thus be developed is discussed under the head of "Power." It may be stated here that at Grand Coulee alone the all-year available power, with Pend Oreille and Priest Lakes used for Columbia Basin gravity project storage is estimated at 640,000 effective horsepower, while with the lakes used for power in connection with a Columbia Basin pumping project, this all-year power is 665,000 effective horsepower (see Pl. 7). The latter power is additional to the seasonal power required for Columbia Basin pumping, and is figured on the basis of nominal flow subject to certain shortages. These shortages during the cycle 1913–1921 would have occurred in the winter season of 1919–20, except as to additional shortage in October, 1915, April, 1917, October, 1919, and April, 1920, when they could have been held down to less than 20 per cent, and in October, 1915, to less than 10 per cent, if the general shortage had been partly assumed by the irrigation side of power, which for months like April in years of late spring, and in October, is assumed to be permissible.

87. It has been argued as an objectionable feature of the pumping plan of Columbia Basin irrigation that the seasonal power used for irrigation pumping varying throughout the season as per column 6 in table, section 79, from about 500,000 to 1,350,000 turbine horsepower would be permanently lost to industrial purposes.

88. The argument, so far as it refers to the necessity of considering the effect on power possibilities in judging the merits and demerits of the two different methods of irrigating Columbia Basin from a public standpoint is correct, but it fails to take into account the destructive effect of a Columbia Basin gravity project on all-year power not only at Grand Coulee, but also at all other future power plants below Albany Falls, which effect will be more fully considered under the head of "Power." As to the power intended for irrigation pumping, it should be clearly understood that this is to be derived from the stream during the irrigation season, when flow is high as compared with winter flow. The nominal flow of the Columbia River is dependent upon the low winter flow. The surplus or secondary power which is available principally during the irrigation season, will probably have material value only for irrigation pumping, and would under the pumping project be so used for the supply of the only large body of good agricultural land which can absorb this power. A large amount of seasonal surplus power is likely to be available at other sites, for all of which it will be difficult to find a satisfactory market because of scarcity of land under a lift which can be economically considered in connection with commercial power transmitted from private plants.

89. A Columbia Basin pumping project may benefit greatly from the all-year power possibilities at the Grand Coulee site. It may be found that the value of this power in relation to its incidental cost will become sufficiently great to materially reduce the net cost of irrigation and to bring the entire project within the limit of economical feasibility sooner by many years than might be the case with the gravity project.

90. As to needs of storage it is concluded that a Columbia Basin gravity project requires Pend Oreille and Priest Lake storage amounting, respectively, to 1,750,000 and 600,000 acre-feet, and that a Columbia Basin pumping project need in itself require no storage, but may be benefited by regulation from storage, if power development is made a part of the irrigation project.

POWER.

91. The profile of the river from Flathead Lake down to Pasco is shown on Plate 8. The average annual flow, the vertical drop, and the potential theoretical power for various stretches of the river have been roughly figured with the following results:

Stream.	Location.	Average annual flow, October, 1913, to September, 1921.	Vertical drop.	Potential theoretical.
Flathead River	Polson to Mouth of Flathead River	11,200	420	534,000
Clark Fork	Mouth of Flathead River to Lake Pend Oreille	20,600	410	963,000
Do	Lake Pend Oreille to International boundary	27,600	320	1,003,000
D	International boundary to Mouth of Clark Fork	27,600	400	1,254,000
Columbia River	Mouth of Clark Fork to Pasco	116,000	1,017	13,402,000
Total			2,567	17,156,000

92. The power which it will be practicable and economical to develop is vastly less. Estimates of such power must be based upon the river flow available for the greater part of the time. For purposes of consistent comparison the nominal stream flow will be used, such as is available either under unregulated or regulated stream flow for 90 per cent of the time.

93. Only a portion of the total head can be utilized. From various sources this board has estimated usable head as follows:

	Feet.
Report to United States Geological Survey of La Rue, 1913, Flathead River, 3 dams	303
Report to United States Forest Service of Kramer, 1921, Clark Fork from mouth of Flathead River to Lake Pend Oreille:	
3 dams in Montana	140
1 dam in Idaho	77

	Feet.
Hugh L. Cooper application, Clark Fork Lake Pend Oreille, to international boundary, 1 dam at Z Canyon	250
Water powers of British Columbia, commission of conservation, Canada, 1919, Clark Fork through British Columbia, 3 dams	265
Application of Washington Water Power Co., Columbia River, Kettle Falls, 1 dam	75
United States Army profile, Columbia River, Grand Coulee, 1 dam	198
Application of Washington Irrigation & Development Co., Columbia River, Priest Rapids, 1 dam	90
Total usable head, 54 per cent of gross head, or	1,398

94. The above dams are shown on the river profile, Plate 8. It will be seen that the drop in the Columbia River of over 400 feet between Grand Coulee and Priest Rapids is assumed as not available for power. This is simply because it is not known that dam sites exist between these two points. Should there be a favorable site at Foster Creek, 50 miles below Grand Coulee, an additional head of 150 feet may become usable, or should the site at Box Canyon, 40 miles below Grand Coulee, prove feasible a dam at this point might be built to a height of 300 feet as compared with 200 feet at Grand Coulee, leaving the pump lift unchanged and increasing commercial power 50 per cent. These possibilities would greatly increase estimates of available Columbia River power and would, as will be later noted, add weight to the arguments upon which deductions as to most beneficial control of storage are based.

95. A further reduction in the estimates of feasible potential power as compared with theoretical power results from the imperfection of machinery. The efficiency of turbines varies with the head and in the following estimates arbitrary percentages are assumed for the over-all efficiency of turbines and generators, dependent upon the average head on the turbines at the dam sites on each successive river stretch.

96. On the basis of measured past flow the estimate is as follows:

Stream.	Location.	Nominal flow 1913–1920.	Head available at dam site.	Assumed over-all efficiency.	Electric horsepower.
		Second-feet.	*Feet.*	*Per cent.*	
Flathead River	Polson to Mouth of Flathead River	2,500	303	80	69,000
Clark Fork—					
No. 1	Mouth of Flathead River to Idaho line	6,300	140	75	75,000
No. 2	Idaho line to Lake Pend Oreille	6,500	77	75	43,000
No. 3	Lake Pend Oreille to International boundary	9,600	250	85	232,000
No. 4	International boundary to Mouth of Clark Fork	9,700	265	80	234,000
Columbia River:					
No. 1	Mouth of Clark Fork to Foot of Kettle Falls	26,000	75	75	166,000
No. 2	Foot of Kettle Falls to Grand Coulee	32,000	198	85	612,000
No. 3	Grand Coulee to Foot of Priest Rapids	36,000	90	80	294,000
Total					1,725,000

97. The total power as figured above on the basis of natural river flow is one-tenth the theoretical power available in the stream for the period 1913 to 1921. This estimate can, however, be raised materially by the use of storage for stream regulation.

98. The use of Flathead Lake storage for power if 1,600,000 acre-feet of controllable storage can be created, will permit a flow to be maintained in Flathead River during a cycle like 1913 to 1921 at all times more than 4,800 second-feet and for 98 per cent of the time more than 6,000 second-feet. Likewise, such use of Flathead storage will raise the flow on the Clark Fork past Plains for 90 per cent of the time from 6,300 to 8,900 second-feet. The power increase resulting from such use as far as Pend Oreille Lake is shown in the following comparision:

Stream.	Location.	With Flathead Lake storage, 1,600,000 acre-feet.				Without storage, electric horsepower.	Increase due to storage, electric horsepower.
		Nominal flow	Head at dams.	Overall efficiency.	Electric horsepower.		
		Second-feet.	*Feet.*	*Per cent.*			
Flathead River	Polson to Mouth of Flathead River	6,000	303	80	165,000	69,000	96,000
Clark Fork	Mouth of Flathead River to Idaho line	8,900	140	75	106,000	75,000	31,000
Clark Fork	Idaho line to Lake Pend Oreille	9,100	77	75	59,000	43,000	16,000
Total					329,000	187,000	143,000

99. The use of Flathead Lake for power, in the event of a gravity supply for the Columbia Basin project, will necessitate this project having control of Priest Lake as well as Pend Oreille Lake. Priest Lake might be used instead for power on Priest River where after storage regulation about 23,000 effective horsepower could be developed. It is understood that permits for the development of power on Priest River and Lake were at one time granted by the United States Forest Service but that all such permits have since been canceled.

100. Irrigation use of Priest Lake in lieu of Flathead Lake will prevent this power development and the gain to Montana and Idaho power will be 143,000 effective horsepower as per previous table, less 23,000 effective horsepower or 120,000 effective horsepower. This figure is probably an underestimate because it represents merely the difference between potential output of power plants with and without storage control. Some of the smaller plants included in the above estimate are likely to prove uneconomical without power storage, the power without Flathead storage may be correspondingly reduced and the figured benefit from power storage

estimated above at 120,000 effective horsepower would be in the same measure increased. It is also probable that the assumed destruction of 23,000 Priest River horsepower may be more apparent than real, as a series of small power plants on Priest River can not be placed on a basis of financial competition with the large unit plants which are sure to be ultimately constructed on Clark Fork in the vicinity.

101. Storage release from Flathead Lake for power will also benefit Clark Fork power below Albany Falls to the extent that the natural flow increase thereby caused is not retained in Pend Oreille Lake for irrigation storage, as more fully explained later.

102. Flathead Lake, if it were permitted to be used for a Columbia Basin gravity project, can be handled so as to give maximum benefit to Flathead and Clark Fork power. It has been claimed that such benefit may be as great as if the lake were controlled with that special object in view. If this were true it would follow equally that Flathead Lake can be controlled by power and yet yield maximum benefit to Columbia Basin irrigation. A special study has been made of this subject to ascertain whether this claim is valid, and it was found that shortages at Flathead power plants with the two methods of control based on 1,600,000 acre-feet Flathead Lake storage and 6,000 second-feet flow installation compare as follows during the cycle 1903–1921:

Month.	Power shortage storage control for benefit of—	
	Columbia Basin gravity project.	Flathead power.
	Per cent.	*Per cent.*
December, 1905	38	0
January, 1906	69	0
February, 1906	64	5
March, 1906	63	0
January, 1907	10	0
February, 1907	40	0
March, 1907	31	0
November, 1919	[1] 58	20
December, 1919	[1] 44	20
January, 1920	[1] 64	20
February, 1920	[1] 73	20
March, 1920	[1] 76	20

[1] Mean 63 per cent.

103. The above figures clearly show that the claim that irrigation control of Flathead storage will not injure potential power on Flathead River can not be sustained. The 1919–20 shortage of 20 per cent for five months, which with reasonably full use of resources is unavoidable, would have been increased to a mean of 63 per cent and

additional and very serious shortages would have been introduced during the earlier part of the cycle. That during years of ordinary or excessive run-off there should be no difference due to the special interest on behalf of which storage water is collected or released, is not surprising. The primary object of reservoirs is to meet the emergency conditions which arise in unusually dry years. It is clear that at such times Flathead power would suffer severely if Flathead Lake is controlled for Columbia Basin gravity irrigation.

104. It should be understood that Pend Oreille storage for a Columbia Basin gravity project during times of storage draft is partly dependent on an outflow from Flathead Lake at least as great as that which would have taken place under natural conditions. It is upon this basis that sufficiency of Pend Oreille and Priest Lake storage for a Columbia Basin gravity project has been found. With fullest practicable storage development in Flathead Lake by Flathead power interests, this condition will automatically obtain. With partial development, however, this may not be the case. Rights given to Flathead power interests in Flathead Lake storage should, therefore, in the interest of a Columbia Basin gravity project, be made subject to full development or if this point is not reached for the time being, to the requirement that at least natural Flathead River flow must be maintained during times of Pend Oreille storage draft if required by such project.

105. In case Columbia Basin could be shown to have absolute need of Flathead Lake, the importance of its future irrigation is so great as to outweigh the destructive effect on power. This, however, is not the case. As has been shown a Columbia Basin gravity project with Pend Oreille and Priest Lake storage can receive a complete supply short only to the extent of 10 per cent for part of one irrigation season in 19 years, while a pumping project can be constructed so that no storage at all will be required.

106. It is therefore believed to be to the best interest of the public that Flathead Lake shall be reserved for the ultimate direct benefit of Flathead power, and for the incidental benefit of interests below. All interests are to a large extent interrelated. It is possible without jeopardizing power development on Flathead to vary the control of storage so as to come to the aid of interests lower down on the stream during times of emergency, and it is obviously advantageous to the public that such control shall not be exercised by Flathead power interests alone. Several States are concerned in the use of this storage, and storage control at all the reservoirs should be exercised by an impartial agency which can fully and equitably regard all interests involved.

107. Release of Flathead storage for Flathead River power will have a decidedly beneficial effect upon Clark Fork power, not only above Albany Falls but also below, unless retained in Pend Oreille Lake for irrigation. Such retention should be broadly permitted but should be subject to proper limitation.

108. Power development of the Clark Fork below Albany Falls should be left as attractive for future development as is compatible with the interests of the Columbia Basin project if built on the gravity plan and with consequent control of Pend Oreille and Priest Lake storage. The nominal flow at "Z" Canyon under past conditions has been 9,600 second-feet and under the gravity diversion plan of the Columbia Basin project will become unavoidably reduced to 7,300 second-feet. A small part of this unavoidable injury may be offset by benefit if part of Flathead power storage release be passed through Pend Oreille Lake instead of being retained therein for irrigation.

109. The natural flow has at times fallen far below 7,300 second-feet. During the period 1903–1921 there was one month when the mean flow dropped to 5,500 second-feet, during one week it fell to 3,610 second-feet, and during one day it was only 2,500 second-feet (December 12, 1919). Extreme low flow in future may be even smaller by reason of increased winter storage for additional irrigation in Montana and Idaho.

110. The storage control as contemplated by the Columbia Basin commission would have been such as to produce a flow during the crucial period 1919–20 no greater than the very low natural flow. Under the allotment of storage control as herein suggested it would have been possible to maintain the flow past Newport at a minimum of 7,000 second-feet during the trying period October, 1919, to January, 1920, inclusive, as well as during the balance of the cycle 1903–1921.

111. The usable head on the Clark Fork below Albany Falls is figured as 250 feet in Washington and 265 feet in British Columbia. The maintenance of a flow slightly above 7,000 second-feet, thereby nearly doubling the natural flow for short periods, is a help to lower Clark Fork power development which would partially offset the damage which these power interests may conceive themselves to have suffered. Such help is urged as a matter not of legal right but of public interest.

112. The above result can and it is believed should be secured after establishment of sufficient Flathead power storage, by limiting the right of a Columbia Basin gravity project to storage of inflow from above in excess of 7,000 second-feet. This requirement will not consume Pend Oreille irrigation storage but will prevent its complete accumulation during periods of extreme low water.

113. Power on Clark Fork below Albany Falls would thus to some extent become dependent on Flathead power storage and should be granted a corresponding interest therein. It is conceivable that power development at "Z" Canyon may precede that on Flathead

River. It is therefore desirable under such condition and should the gravity plan of Columbia Basin irrigation be adopted to permit "Z" Canyon interests to create artificial storage for their own benefit at Flathead Lake, subject, however, to the condition that when the demands of a Columbia Basin project may so require, water be released in amount at least equal to what would have been the Flathead Lake natural outflow and subject further to ultimate direct control principally for Flathead power interests, when these interests are prepared to develop Flathead Lake to the full practicable extent.

114. In the event the Columbia Basin project is supplied by pumping, Pend Oreille and Priest Lake storage should be used for the joint benefit of power developments below. A comparison between power possibilities on the lower Clark Fork and the Columbia River under condition of either gravity or pumping supply for the Columbia Basin project may be made from the following table:

Stream.	Location.	Head at dam.	Efficiency.	Columbia Basin supplied by—			
				Gravity.		Pumping.	
				Nominal flow.	Electric horsepower.	Nominal flow.	Electric horsepower.
		Feet.	*Per cent.*	*Second-feet.*		*Second-feet.*	
Clark Fork No. 2	Lake Pend Oreille to international boundary	250	85	7,300	176,600	18,000	435,000
Clark Fork No. 3	International boundary to mouth of Clark Fork	265	80	7,460	178,000	18,100	440,000
Columbia River No. 1	Mouth of Clark Fork to foot of Kettle Falls	75	75	27,900	178,000	35,200	225,000
Columbia River No. 2	Foot of Kettle Falls to Grand Coulee	198	85	33,100	640,000	35,000	665,000
Columbia River No. 3	Grand Coulee to foot of Priest Rapids	90	80	36,000	294,000	42,500	348,000
					1,466,000		2,113,000
Difference							647,000

115. The figures in the last column are predicated on the use of Priest Lake storage for regulating the flow for power below Albany Falls. Such storage may also be used for the development of Priest River power, thereby producing about 23,000 effective horsepower, as outlined in paragraphs 99 and 100. The lake was figured for 600,000 acre-feet storage, or about one-fourth of the combined storage in Pend Oreille and Priest Lakes. As the increase of power on Clark Fork and Columbia River made possible by the control of both lakes is shown to be about 647,000 effective horsepower, it is evident that surrendering one-fourth of this storage to local power on Priest Lake may result in a loss lower down of possibly 160,000 effective horsepower as against a probable local gain on Priest River of 23,000 effective horsepower. Thus the use of Priest Lake for local power is equally inadvisable in the case of a pumped supply as it was shown to be in the case of a gravity supply for the Columbia Basin project.

116. In the above comparison the Grand Coulee Dam has been assumed as 200 feet high, the water being raised to a minimum elevation of 1,138 feet. It should be stated that such height of dam may have an injurious effect on power possibilities on the lower Spokane. So far as known, there are two favorable dam sites on this stream, one 2 miles and the other 18 miles above its mouth. The latter site will not be interfered with by a 200-foot Grand Coulee dam. The former site would be submerged at least 50 feet by the Grand Coulee Dam, and the remaining 50 feet of a total of 100 feet head otherwise available at this site would be destroyed unless a 50-foot dam should be feasible upstream of the point reached by Grand Coulee back water. The nominal flow on Spokane River, as controlled by Coeur d'Alene storage, is about 2,500 second-feet as compared with over 30,000 second-feet at Grand Coulee, and the loss of Spokane River power, if a 50-foot dam above Grand Coulee back water should not be feasible, would be but a fraction of the gain on the Columbia River by building the Grand Coulee Dam to maximum permissible height.

117. A summary of all power possibilities under various assumed conditions is given in the following table, together with the extent of estimated shortages:

All-year power on Flathead River, Clark Fork, and Columbia River.

Stream.	Location.	Usable head at dam sites.	No storage.		Flathead storage, 1,600,000 acre-feet for Flathead power. Pend Oreille storage, 1,750,000 acre-feet. Priest Lake storage, 600,000 acre-feet for—				State or Province.
			Nominal flow.	All-year power.	Columbia Basin gravity project.		Power.		
					Nominal flow.	All-year power.	Nominal flow.	All-year power.	
		Feet.	*Second-feet.*	*Effective horsepower.*	*Second-feet.*	*Effective horsepower.*	*Second-feet.*	*Effective horsepower.*	
Flathead River	Flathead Lake to mouth of Flathead River	303	2,500	69,000	6,000	161,000	6,000	165,000	Montana.
Clark Fork:									
No. 1	Mouth of Flathead River to Idaho line	140	6,300	75,000	8,900	106,000	8,901	06,000	Do.
No. 2	Idaho line to Lake Pend Oreille	77	6,500	43,000	9,100	59,000	9,100	59,000	Idaho.
No. 3	Lake Pend Oreille to international boundary	250	9,600	232,000	7,300	176,000	18,000	435,000	Washington.
No. 4	International boundary to mouth of Clark Fork	265	9,760	234,000	7,400	178,000	18,100	440,000	British Columbia.
Columbia River:									
No. 1	Mouth of Clark Fork to foot of Kettle Falls	75	26,000	166,000	27,900	178,000	35,200	225,000	Washington.
No. 2	Foot of Kettle Falls to Grand Coulee	198	32,000	612,000	33,100	640,000	35,000	[1] 665,000	Do.
No. 3	Grand Coulee to Priest Rapids	90	36,000	294,000	36,000	294,000	42,500	348,000	Do.
Total				1,725,000		1,796,000		2,443,000	
Difference								647,000	

[1] Additional to seasonal power for Columbia Basin pumping project.

Shortage in all-year power on Flathead River, Clark Fork, and Columbia River, 1913–1921.

Stream.	No storage.			Flathead storage, 1,600,000 acre-feet for Flathead power. Pend Oreille storage, 1,750,000 acre-feet. Priest Lake storage, 600,000 acre-feet for—					
				Columbia Basin gravity project.			Power.		
	Number of months.	Average per cent.	Maximum per cent.	Number of months.	Average per cent.	Maximum per cent.	Number of months.	Average per cent.	Maximum per cent.
Columbia Basin irrigation				4	10	10	9	12	[1] 60
Flathead River	10	19	40	5	20	20	5	20	20
Clark Fork No. 1	9	15	43	9	7	19	9	7	19
Clark Fork No. 2	9	15	43	9	7	19	9	7	19
Clark Fork No. 3	9	19	42	11	1	1	6	28	28
Clark Fork No. 4	9	19	42	11	1	1	6	28	28
Columbia River No. 1	9	12	21	9	14	29	9	14	27
Columbia River No. 2	9	15	25	9	14	26	9	13	20
Columbia River No. 3	9	15	24	9	12	22	9	11	21

[1] April, 1920.

118. The all-year power possibilities on the river system aggregate as follows:

	Electric horsepower.
With Columbia Basin irrigated by pumping	[1] 2,443,000
With Columbia Basin irrigated by gravity	1,796,000
Difference	[1] 647,000

119. In the 1920 report of the Columbia Basin commission under the head of "Power possibilities" in connection with a Columbia Basin gravity project it was stated that seasonal power could be ultimately developed from local canal drops varying from 70,000 horsepower in April to 190,000 horsepower in August and to 80,000 horsepower in October, no power of course being available for the five months from November 1 to March 30. No statement occurs in the report of similar seasonal power which will be available under a pumping project and no information is at hand upon which to base an estimate of the difference in this seasonal power from canal drops which may exist in favor of the gravity project.

120. It is possible that this difference may be material and this subject should of course be fully investigated. For present purposes it may be said that such seasonal power from canal drops can not compare in value with all year power, especially since at all power developments on the Clark Fork, and particularly at those on the Columbia River, large amounts of seasonal power will become available, probably far in excess of what can be feasibly consumed by irrigation.

[1] May be subject to a reduction of 11,000 horsepower in the event of power destruction on the lower Spokane River.

121. Statements have been made to this board that a Columbia Basin gravity canal might be utilized in winter to deliver water into the Spokane River above Spokane for power use by plants lower down on the stream. In this manner the water might be used under an aggregate head of about 680 feet on the Spokane River including plants not yet built as against 515 feet usable head on the lower Clark Fork and 75 feet in Kettle Falls, all above the point of return to the Columbia River.

122. The extent to which such use of water may be valuable to Spokane River power plants has not been studied and may depend upon methods of regulating storage in Coeur d'Alene Lake which may in this manner permit saving of storage in winter for use during the rest of the year. The injury to interests on lower Clark Fork and at Kettle Falls is, however, evident. The result would be not merely the destruction of practically the same power as that created on Spokane River, but also by reason of leaving no Clark Fork power available in winter, the conversions of all year power on Clark Fork and to some extent at Kettle Falls into seasonal power of much less value.

123. As a practical proposition the use of a long and important irrigation canal for flow of power water during winter is objectionable because there remains no time available for doing the necessary annual repairs and because the rate of depreciation of concrete canal lining is greatly increased by carrying water under ice conditions.

124. Finally, the legal right of completely laying dry a large river for several months in each year, both in the United States and in Canada, may be seriously questioned.

125. From the preceding discussion it is evident that a decision between the methods of irrigating the Columbia Basin affects not only the project itself but also future power possibilities, of which nearly 650,000 all-year effective horsepower would be destroyed by the selection of the gravity method. If it were now decided that the pumping method is the proper solution, power development on the lower Clark Fork and on the Columbia River could be based upon a system of Pend Oreille and Priest Lake storage control highly beneficial to power. If, on the other hand, the gravity method were to be definitely selected, power interests will have to judge their prospects and possibilities on a correspondingly reduced basis and act or fail to act accordingly.

126. This board is not prepared to express an opinion on the immediate feasibility of a Columbia Basin project, but considers it evident that if the project is not feasible now, rising land values will render it so in the future, and that its economic importance is relatively greater than that of the power which it may destroy.

It is further believed that satisfactory information is not now at hand to justify a final decision on the method of irrigating the Columbia Basin or even on the best location for the dam for a pumping project that will be to the best interest of the public. This board feels that the pumping and the gravity methods of supply have each their strong and their weak features, but is of the opinion that the project investigation, upon which to date less than 10 cents per acre has been expended, has not gone nearly far enough to permit a convincing decision, especially considering that the adoption of the gravity project may result in the permanent destruction of about 650,000 all-year effective horsepower nearly 400,000 of which is located in the State of Washington.

127. There is a tendency to underestimate the value of power in localities such as the Northwest where potentialities are very great. While this tendency may continue in the Northwest for some time, a change in this attitude toward undeveloped water power may be anticipated. The demands of an increasing power market are being felt all over the United States. For instance, California, where 20 years ago a great excess of power was available, is now finding its industrial development hampered by inability to keep ahead of demands for power. The Columbia Basin when developed will in itself become a large consumer of power and increase power consumption in the surrounding large cities. Improvements in chemical and electrolytical processes demanding low cost power may also be confidently expected in the future. It is probable that power development in the Northwest, which is now steadily proceeding, will be greatly accelerated and that before long the value of potential power will be more generally appraised at its real value.

128. As regards facilitating power development below Lake Pend Oreille pending a decision as to the proper method of irrigating Columbia Basin, it may be stated that in addition to granting the use of Flathead Lake for the power interests below Flathead River under reservations outlined in section 93, there appears to be no objection to the Federal Power Commission granting also rights of storage in Pend Oreille and Priest Lakes to power interests provided such rights are made subject to cancellation in the event that a gravity supply is finally decided upon for the Columbia Basin project.

RELATIONS WITH CANADA.

129. The flow in the lower Clark Fork will be materially affected by a decision as to methods of storage control in Flathead, Pend Oreille, and Priest Lakes. After crossing from Washington into British Columbia the Clark Fork has a drop of 400 feet, of which, according to the Canadian commission of conservation, 265 feet may

be available for power development. Potential feasible power may be estimated, as per table in section 92, at 234,000 effective horsepower under conditions of present flow, 178,000 effective horsepower in case the Columbia Basin project is irrigated by gravity, and 440,000 effective horsepower in case this project is irrigated by pumping.

130. Careful consideration is owing to the interests of our neighbor on the north, although not to the extent of causing serious injury to ourselves. Thus power loss or gain in Canada should exercise no decisive influence upon the solution of our domestic problems. It is, however, of importance that if by any action south of the line, no matter how well within the bounds of international legality, interests to the north may be injured, this injury be kept down to a fair minimum.

131. The proposition previously outlined that the right of storage of a Columbia Basin gravity project should be limited to the total inflow in excess of 7,000 second-feet should gain weight when fair consideration is given to the interests of Canada. The question of division of cost in proportion of benefits need not herein be discussed.

132. It is of course necessary to live up to our agreements with Canada as expressed in existing treaties. One treaty requires that an open river shall be maintained from the international boundary to the ocean. This treaty may be considered as providing for navigation use on the river by Canadians on equal terms with citizens of the United States.

133. If, however, this treaty is to be interpreted as forbidding the building of dams without provisions for passing boats or logs, and the treaty should not be abrogated by common consent but should remain in effect when definite rights are to be granted at Grand Coulee or elsewhere on the Columbia River for the construction of a dam, it devolves upon our Government to insist upon provisions for the construction of locks. In this event, however, agreement of Canada to postponement of actual construction might be secured through the State Department until the locks are found necessary for purposes of navigation.

134. Reference has been had to the effect which the control of storage in certain large lakes in British Columbia may have upon the flow of the Columbia River in the United States. It was stated in section 6 that information received from Dominion and Provincial authorities leads to the preliminary conclusion that the effect will not be serious. Undoubtedly, Canada in the exercise of its authority will require that no avoidable injury will be inflicted on interests in the United States.

CONCLUSIONS.

135. It is concluded that—

(*a*) Freedom should be given to fullest irrigation expansion in Montana, Idaho, and Washington, and no rights should be allowed to accrue to lower interests which would legalize limitation of or interference with irrigation above.

(*b*) The Columbia Basin project is the most important single item to be considered in the uses to be made of Columbia River water above the mouth of Snake River.

(*c*) The Columbia Basin project can be irrigated by gravity from the Clark Fork at Albany Falls or by pumping from the Columbia River at Grand Coulee.

(*d*) The Columbia Basin gravity project can be adequately supplied by the aid of storage in Pend Oreille and Priest Lakes in Idaho, conditioned upon maintenance of natural flow from Flathead Lake when needed.

(*e*) The Columbia Basin project can be supplied with practically no shortage without the aid of storage, with a dam at Grand Coulee about 156 feet high above low water.

(*f*) Information upon which to base a final decision between a gravity and a pumped supply for a Columbia Basin irrigation project is not complete and should be completed. Any decision should take into account the effect upon potential power.

(*g*) Pending such decision no permanent rights of storage should be granted in Pend Oreille and Priest Lakes.

(*h*) If ultimately the decision is in favor of a Columbia Basin gravity project, storage rights in Pend Oreille and Priest Lakes should be granted to such project, but should be limited to storage of inflow in excess of 7,000 second-feet.

(*i*) If ultimately the decision is in favor of a Columbia Basin pumping project, storage rights in Pend Oreille and Priest Lakes should be granted to the joint interests of power on the lower Clark Fork and the Columbia River, subject to limitations contained in section (*a*).

(*j*) Storage rights in Flathead Lake should be granted to Flathead power interests, subject to fullest development found practicable after complete investigation. Prior to such development rights may be advantageously granted to power interests on Clark Fork subject to conditions protecting ultimate control for Flathead power and for the protection of the Columbia Basin project if built on the gravity plan.

(*k*) Storage control at Flathead, Pend Oreille, and Priest Lakes should be under impartial supervision.

(*l*) A permit to develop power at the Grand Coulee site or at any point on the Columbia River as far downstream as the Foster Creek site should not be granted to power interests until it is known that such site will not be needed by the Columbia Basin project. In case the Columbia Basin project shall require a power site for irrigation and power on this stretch of the Columbia River a permit should be granted to it after the best location and height of dam shall have been determined from the standpoint of the project and the public interest.

IV. MINORITY REPORT, BY MARVIN CHASE, SUPERVISOR OF HYDRAULICS, STATE OF WASHINGTON (MEMBER, COLUMBIA RIVER BOARD).

In submitting a minority report, it is desired to state that the writer concurs in the foregoing majority report, except as to the conclusions, recommendations, and discussion relating to the Columbia Basin project. The reasons necessitating a dissent from those features of the majority report are stated in the following pages.

The Columbia River board is a board of engineers, appointed by the Federal Power Commission, to make a study of the most economic use of the waters of the Columbia River, and report its findings and conclusions to the Federal Power Commission. It must be borne in mind at all times throughout this discussion, however, that the Federal Power Commission has jurisdiction over the waters of the Columbia River only in so far as the use of water for power development is concerned. A reading of the majority report will disclose that it is devoted largely to a study of the Columbia Basin project. In thus concentrating on irrigation the board has gone beyond the scope of its authority. For instance, of the board's 12 conclusions only 2 are of general application, the remaining 10 dealing with the Columbia Basin project.

Before considering the power development from the Columbia River, the board necessarily had to devote some attention to the irrigation needs, and the interrelation of irrigation and power uses. The board has recognized that "freedom should be given to fullest irrigation expansion in the States of Montana, Idaho, and Washington." With this fundamental conclusion, the writer fully concurs. It is a timely recognition of the need of the Northwest for greater agricultural development and of the priority which should be accorded irrigation.

The largest single proposed use of the waters of the Columbia River is for the irrigation of lands within the Columbia Basin project in the State of Washington. Before studying power needs, it is granted that the board had to take into consideration the amount of water needed for that project and the proposed point of diversion. The board's problem, there, however, was a very simple one. The

State of Washington, through its properly authorized officers had prepared complete and elaborate data on that project. The State's report had discussed alternative reclamation plans. Subsequently to the issuance of that report, the State had procured a further report from Maj. Gen. Geo. W. Goethals and as a result of his recommendations, the proper officials of the State had officially approved and selected the gravity plan, and had so advised the Columbia River board. The Columbia River board should have accepted the State's conclusion.

The majority report follows such procedure in considering irrigation needs in the States of Montana and Idaho. (See pars. 58 and 61, majority report.)

Had the board, in its majority report, thus remained within the scope of its proper jurisdiction, there would have been no occasion for a minority report. But unfortunately the majority of the board have not only overstepped their authority, but have insisted in disregarding the official action of the State of Washington, and have devoted the greater portion of their report to a study of the alternative features of the Columbia Basin project. They have converted what should have been an impartial analysis of power possibilities into a criticism of and argument against the decision of the proper officials of the State of Washington. The majority of the board are presuming, as representing a Federal commission, to recommend to that commission action which would infringe and trespass upon the supreme right of a sovereign State to regulate its own internal affairs.

The detailed consideration of the Columbia Basin project has no proper place in a report of the Columbia River board to the Federal Power Commission, but having been injected into the majority report, a minority report to analyze the majority treatment of that project becomes a necessity. It is not deemed advisable at this time to reiterate the special features of that project. They are summarized in Appendix D accompanying the majority report. In order, however, that the Federal Power Commission may have no misunderstanding of the position of the State of Washington, we are attaching to this minority report, and by reference making a part hereof, Exhibit 1, "Columbia Basin Project, with Appendices. 1920," being a report by the Columbia Basin Survey Commission; and Exhibit 2, "Columbia Basin Project, a Report by George W. Goethals & Co. (Inc.), 1921." [1]

The majority report gives 12 conclusions, which are designated (*a*) to (*l*), inclusive. These conclusions will now be considered in the order in which they occur.

[1] Printed and distributed by the State of Washington.

(*a*) Freedom should be given to fullest irrigation expansion in Montana, Idaho, and Washington, and no rights should be allowed to accrue to *lower* interests which would legalize limitation of or interference with irrigation *above*.

This conclusion leaves it possible for *upper* interests to limit or interfere with *lower* irrigation. That is, power development at any point above Albany Falls could limit irrigation development at any point below the falls. This is exactly contrary to the first part of the conclusion that correctly states "Freedom should be given to fullest irrigation expansion." The conclusion should be modified to read: "(*a*) Freedom should be given to fullest irrigation expansion in Montana, Idaho, and Washington, and no rights should be allowed to accrue to other interests which would legalize limitation of or interference with irrigation."

Conclusion (*b*) logically follows conclusion (*a*) if the latter is modified as requested.

Conclusion (*c*) involves the board in a controversy which should not be reopened, wherein it states that the Columbia Basin can be irrigated by pumping from the Columbia River at Grand Coulee. The official finding by the State of Washington whereby the State adopted the Columbia Basin gravity plan closed that controversy. There is no other official plan available for consideration.

Conclusion (*d*) is only possible if storage is provided in Lake Pend Oreille to elevation 2,070 and even then some shortage of irrigation water must be expected. The Columbia Basin Survey Commission had a crew appraising land damages around the lake for nearly two months and arrived at the conclusion that elevation 2,065 was the highest desirable when all factors are considered. A committee of two members of this board of engineers spent one day at Sand Point on the lake, and upon their advice this report adopts elevation 2,070.

Conclusion (*e*) not only is subject to same objection as conclusion (*c*), but does not agree with the tables of water supply given elsewhere in the report. In a number of years there will be shortage of water at either the beginning or the end of the irrigation season. The report dismisses this by saying that a low flow in April would be accompanied by a low demand for irrigation water, but this does not follow. The run-off from the high Rocky Mountains and the British Columbia area might be very slow and late in the year, yet an early spring with extreme drought conditions be found over the irrigation area. And in the fall, an unusually low run-off might be the result of a widespread and long continued drought, which would multiply the demand for water for irrigation.

Conclusion (*f*) does not come within the province of this report, or of the Federal Power Commission. The question of alternate sources of supply for the Columbia Basin project is not before this board, or any other part of the Federal Government at this time.

Conclusion (*g*) is just the reverse of the fact. Whether the gravity or the pumping plan is adopted for the Columbia Basin, storage in the lakes will be essential to a full and properly maintained water supply. It is admitted the gravity plan will need the maximum storage of Pend Oreille and Priest Lakes. It is also shown by the board's own figures that the pumping project depends largely upon sale of surplus power to reduce the probable net operating cost to anywhere near feasible limits, and the same figures show that large storage in probably all three lakes will be necessary to maintain a primary or firm output of commercial power at the Grand Coulee site in excess of that required for pumping. Under either project, therefore, maximum storage is required in the lakes for the benefit primarily of irrigation. The conclusion should therefore read: "(*g*) Permanent rights of storage in Pend Oreille and Priest Lakes should be reserved for the irrigation projects in the States of Washington and Idaho."

Conclusions (*h*), (*j*), (*k*), and (*l*) are accepted, although subject to the general contention that the pumping project is not properly before this board for consideration.

Conclusion (*i*) is incorrect. It is based upon the assumption by the majority of the board that storage will not be required in connection with the pumping project, whereas the figures tabulated elsewhere in the report show plainly that maximum development of power at a dam at the Grand Coulee site, regardless of the height of dam, requires the maximum possible storage at all points further upstream. It is evident that control of such storage by power companies whose sales are in competition with the power from the Grand Coulee Dam might be exercised in a way very detrimental to the latter. The modification requested in conclusion (*g*) will eliminate necessity for conclusion (*i*). Furthermore, the majority argument and figures showing the greatly superior value of a given amount of water for generating power at the Grand Coulee site, based upon the assumed greater head, volume, and operating efficiency, also show that that site should have the primary control of all storage. Sites which generate a less amount of power per unit of water flowing certainly should not have the control of the flow. Conclusion (*i*) should be eliminated and the modified conclusion (*g*) should be adopted.

If the several changes requested are made in the conclusions, then the recommendations and beliefs expressed in paragraph 16 of the majority report will have the full approval and concurrence of the undersigned.

Chapter III of the majority report contains several statements which are not in accord with our knowledge of the facts. These are discussed in the following paragraphs, numbered to correspond with the numbers in the majority report.

(50, 51, 52). It is necessary to waive our fundamental objection to any consideration of the pumping scheme, in order to place before the Power Commission a correct view of the factors which would be involved if the pumping scheme were still being studied as an alternate to the gravity plan. This is done for the purpose stated, but without granting in the slightest degree that there is any longer either official or unofficial recognition or even a bona fide and sincere proposal that the Columbia Basin should be watered by pumping.

The statement in paragraph 50, "The selection between these two points will have a grave effect upon power possibilities, especially on the Clark Fork below Albany Falls, both in Washington and British Columbia," taken in connection with the other scattered arguments, is intended to create an impression that there would be a resultant loss of total power possibilities. Reference is made to Chapter II, of the brief submitted at Spokane on behalf of the State of Washington. It is shown there and has not been controverted at any point in the board's studies, that the gravity project will increase the *commercially available* potential power by approximately 1,000,000 horsepower. True, a portion of this will be generated at the Columbia and Spokane sites rather than at the Z Canyon site, but this is an advantage since those sites are nearer to markets, cities, established transmission lines, and adequate railway facilities.

(53). We object to citing "prospective rates of land settlement" as an unknown but essential factor of feasibility of the Columbia Basin project, but in paragraph 70 assuming "that, with a growing power market, the cost of irrigation can be reduced materially through the gradual development and sale of the power." Fair play suggests that both settlement rate and the power market be considered alike, either as certain or as uncertain. In fact, every consideration indicates that settlement is more certain than the growth of demand for this particular power. Irrigation is always followed by settlement but the power demand in this State will likely be satisfied by the several very large developments now under way, notably the Skagit, Priest Rapids, and Kettle Falls, totaling probably well over 1,000,000 horsepower and tripling the total water power now developed in this State. These plants give every promise of being in full operation before the Columbia River pumping scheme could possibly be completed, and they would, therefore, have captured the market and would be in position to greatly delay, if not prevent, the profitable sale of the Grand Coulee surplus power.

(68). The majority report makes a statement relative to the work of the State Columbia Basin studies, which is not strictly in accord with the facts. It states, relative to bedrock at Grand Coulee site, "its elevation under the river is at much less depth than was assumed by the commission." Rock was found on a nearly level plane 2,500

feet wide at about 60 feet below low water surface, or about 880 feet above sea level. The commission's original drawings show an assumed elevation of 836.5 for a distance of 1,850 feet, rising rapidly at each end. The actual drilling showed a much greater depth to rock on both sides of the river than was assumed by the commission. Hole No. 8 showed a depth of 217 feet where the original estimate assumed rock practically at the surface, and hole No. 14 showed a depth of 152 feet where the original assumption was less than 50 feet. The actual drilling showed a more expansive and difficult task in excavating for foundations than was assumed by the State commission. It also showed that where rock had been assumed as foundation for the temporary diversion channel, sand and clay are actually present, necessitating extensive sheet piling and other protection for the diversion channel.

(70). The Columbia River board of the Federal Power Commission were advised that a State Columbia River board of engineers and geologists had examined a portion of the Columbia River for the "purpose of determining the location on the river at which borings should be made to ascertain the feasibility of a dam which would be required in connection with the alternate plan of pumpage development of the Columbia Basin project"; that such board had chosen the Grand Coulee site for drilling, and had recommended that an estimate be made of the cost of electric development at the Foster Creek site, assuming feasible dam site, with transmission of the power to Grand Coulee for pumping development. Mr. W. T. Batcheller, an electrical engineer, was employed to make this estimate of electrical development, transmission, and pumping plant at the Grand Coulee site. He was not authorized by any official of the State to do any other work whatsoever, and was not competent either through training or experience, to undertake study of canals, water distribution, or any other portion of the irrigation project. We have at all times emphatically protested against his statements, except upon the matters covered by his official employment, being given greater weight than merely personal opinions not based upon qualified judgment.

The majority report, therefore, is incorrect in referring to studies showing low cost of commercial power, etc., as having been made "for the State." Such reference implies that the State is in some degree responsible for such figures. Not only is this implication untrue, but the figures themselves are mathematically inaccurate in the fundamental assumptions, and the State repudiates any connection therewith.

(72) The majority report errs in stating "Batcheller used such data as were available in the Columbia Basin survey office to make a paper location of the assumed secondary pumping plant and high

canal, and has based his estimate thereon." The maps hanging on the walls of that office, as well as the great mass of field notes representing over 1,200 miles of precise wye-leveling, show that the Batcheller paper location reaches elevation 1,750 southeast of Ritzville where it runs for miles across a great plain, yet at the intake of that canal the elevation is but 1,536 plus 200 feet pumping lift, or 1,736. In a distance of nearly 100 miles the canal must fall certainly not less than 250 feet, yet his discharge end as located on the map is actually *higher* than the intake. The Batcheller line at Benge lies some 40 miles east of the commission's line at Warden, yet the United States Geological Survey topographic map of Connell quadrangle shows that a line 200 feet higher than the commission's canal location would lie from 3 to 5 miles farther east. Further comment on this paper location is needless.

The majority report, however, states "So far as its inspection in the field is concerned, no greater obstacles were noted to a high line pump canal than exist along the gravity canal in this section of the project." This statement is true in that "no greater obstacles were noted," since the board of engineers did not visit this area and made no field inspection of this high line location.

(73) The board again errs in saying that "The 350,000 acres of land in regard to which doubt was expressed as to its quality overlaps about 300,000 acres of land listed as irrigable in the gravity project." The land classification maps of the Columbia Basin survey are available to the board of engineers. These show that approximately 300,000 acres in the overlapping area were rejected by the State commission, and while within the territorial boundaries of the project, are not within the irrigable classification, and are not included as part of the 1,753,000 acres which constitute the irrigation project. The State's claim is correct, i. e., even if such a secondary pumping canal were physically possible, it would not create a project as large as that coverable by gravity.

(74) This paragraph is wholly in error. There is positive evidence, based upon carefully conducted and very extensive field surveys showing conclusively that the pumping scheme will cover a much smaller area than the gravity plan. Reference is made to "areas of excellent land lying above the primary pump canals in various parts of the project." No such areas exist other than those likewise reachable by pumping from the gravity canals, using cheap power developed at the drops in those canals, as shown in the Columbia Basin 1920 report.

There is a persistent effort to ignore the fact that the State commission made a complete classification not only of all lands within the gravity lines, but of a large amount of adjacent lands. The State

records do contain a great amount of accurate and detailed information along the lines referred to, and it is not true as frequently stated in the majority report that "only field surveys can determine" this or that. This information in many cases is at hand, but either no effort has been made to study it by the board of engineers or the presentation made by the representatives of the State of Washington has been wilfully ignored. Judging by the statements in the majority report, the proponents of the pumping scheme have been believed in toto, while the written documents submitted by the State of Washington, and based upon three years of careful field surveys and expert studies, have been discarded.

(86) It appears from this statement that only 25,000 horsepower is added to that commercially available, by requiring the basin project to use the pumping scheme instead of the gravity plan. Even this is subject to material shortage at least six times during the past eight years. To build a dam nearly 300 feet high above foundation (for 200 feet effective head) and two great reservoirs in Idaho for generation of 25,000 horsepower of uncertain continuity, can not be considered as an alternate to the State's official plan. The latter plan would use the lakes for a gravity supply, and allow the full power possible at the Grand Coulee, stated by the board as 640,000 horsepower continuously, plus the enormous seasonal power if marketable, to be developed and used for commercial purposes, if and when a demand arises for such power.

(94). This is misleading. It states that "over 400 feet drop between Grand Coulee and Priest Rapids is assumed as not available for power. This is simply because it is not known that dam sites exist between these two points." The fact is that existing towns of considerable importance, as well as railways upon the banks of the Columbia River, and considerable agricultural development, all prevent any considerable flooding by back water and render a commercial development of a high dam unprofitable.

The further reference to possible favorable sites at Box Canyon and Foster Creek is untenable in view of the unanimous expression of the members of the board of engineers while at the Foster Creek site and the similar expression of the State Columbia River board of engineers and geologists at the Box Canyon site. These expressions were to the effect that even visual evidence was sufficient to show that there was no possibility of either site being suitable for a high dam. Drilling might show suitability for a low structure but the higher abutments, on the north at Foster Creek and on the south at Box Canyon, are lacking for a high structure.

(121). The only comment on this is to call attention to the unfairness of referring to the Spokane River, "including plants not yet built," and referring to Clark Fork and Kettle Falls without comment.

The fact is, 456 feet of the possible 680 on the Spokane is already dammed, whereas none of the 75 feet at Kettle Falls or the claimed 515 feet on Clark Fork has been developed. And so far as Clark Fork is concerned, there is not in sight any serious proposal for development of any part of this fall. Especially is there no thought of developing the 265 feet fall beyond the international boundary. Now is it apparent why any burden should be placed on a proposed American irrigation project in order to benefit a theoretical Canadian power plan?

(123). This argument falls completely, in the light of the many years of successful operation of canals in countries where ice conditions prevail much more severe than any possible in the Spokane country. Niagara alone is sufficient answer to this fallacious statement. Under this theory the vast development now under way in Ontario—the Chippewa—is absurd.

(124). The object in this statement is not clear, as there has been no proposal by the State of Washington to completely dry the Clark Fork or any other stream. The gravity project proposes to maintain 7,000 second-feet down the stream whenever the water is in the stream or can be released from storage.

(126). It is not evident why the majority report intimates that the data acquired by the State of Washington are not accurate nor reliable. Nor does the expenditure of 10 cents an acre by the State have any bearing upon the Federal Power Commission's duties.

The facts are as follows: One hundred and fifty thousand dollars of direct appropriation by the State of Washington; $110,000 directly on the Palouse project study; an unknown but large sum spent by the Department of Agriculture upon the soil surveys of Franklin County and the Quincy Valley area; the complete land classification carried out by the Northern Pacific Railway Co.; the studies made by the several mortgage companies and loan banks; the surveys made by the United States Reclamation Service; the topographic maps made by the State geological survey in cooperation with the Federal Geological Survey of parts of the area; the enormous mass of surveys and other data acquired by the several railroads traversing the area; the 30 or more years of rainfall records by the United States Weather Bureau; the many years of stream flow records by the water resources branch of United States Geological Survey, and the several States; the studies of La Rue and Jessup on the storage lakes; river profiles from the War Department; and a large amount of materials, supplies, and personal labor donated and money expended by various persons, commercial bodies, and State institutions, such as the College of Agriculture and the State geological survey, were all used to the fullest possible extent by the State commission. The long time records of rainfall and stream flow were of untold value to the project, and could

not have been produced by any amount of money had they not already been in existence.

In brief, the information available for the decision upon which the State based its official acceptance of the gravity plan could not have been obtained by original field work and studies for less than a very large sum, probably more per acre than has been ordinarily spent by the existing successful irrigation projects in advance of actual starting of construction.

As stated in the briefs heretofore referred to, the gravity plan does not entail destruction of potential power comparable with the permanent loss of commercial power due to harnessing a maximum of over 1,000,000 horsepower perpetually to the Grand Coulee pumps. The Columbia River dams should be devoted exclusively to commercial power. The large minimum flow and the high heads available may make possible a power development at attractive figures, and the manufacturing industries of the future should have the benefit of this cheap power. It is not logical to expect that the pumping project could charge a price for power which would show a substantial profit for reducing the irrigation cost and expect commercial interests to buy such power instead of buying from other plants on the same stream, having available the same quantity of flow and perhaps more cheaply developed plants and not burdened with a cost load properly chargeable to irrigation.

If an attempt is made to force the power sales to carry part of the irrigation cost, it is absolutely certain and absolutely just that other plants not so charged will quickly take away the commercial demand. The net result will be an increased burden on the irrigators and a loss of commercial power from the State's resources.

CONCLUSION.

The writer regrets that the revisions offered to the board on May 25, 1922, were not acceptable to the majority members. This makes necessary a minority report to call the attention of the Federal Power Commission to the ignoring of data and overriding of State rights evidenced by the majority report. The discussion has been necessarily confined to pointing out obviously incorrect passages in the majority report with which issue is taken.

It is important, amidst the extensive array of details and numerous assertions, that the Federal Power Commission keep clearly in mind certain vital principles involved in this study of plans for the most economic use of the waters of the Columbia River. It is desired briefly to recapitulate some of these important features.

1. The use of the water of the Columbia River for irrigation is of greater benefit to the people of the United States in general, and of the Northwest in particular, than its use for power.

2. The published reports of the United States Reclamation Service and other investigations show that the irrigated lands in the arid portion of Washington yield greater returns per acre and per dollar of capital cost than elsewhere. This is due to the wonderful fertility of the soil, the exceptional climatic conditions, and the progressiveness of the population in adopting the best methods.

3. For these reasons, construction of the officially adopted Columbia Basin gravity project, for the irrigation of 1,753,000 acres of arid land in the State of Washington, is a matter of supreme importance to the people of that State. It is in fact one of the important national problems awaiting solution at this time.

4. The Federal Power Commission, while having no jurisdiction over irrigation, should recognize the superiority of right for irrigation of this vast project, and should grant no power rights which might conflict with this irrigation development.

5. The Columbia River board has evaded its duty by not considering and recommending an arrangement of power development on the Flathead, Clark Fork, Spokane, and upper Columbia River which would yield the maximum commercial power, near existing and probable markets, subject to the superior use of the waters for irrigation of the greatest possible area.

6. The State of Washington having officially adopted the gravity project for the reclamation of the Columbia Basin lands, the Federal Power Commission should not become involved in any controversy as to other possible means of reclamation, but should cooperate with the State to forward the early development of this area, thereby creating new power markets and leading to the maximum utilization of the water resources of the Columbia River.

APPENDIX A.

NAVIGATION ON COLUMBIA RIVER AND ITS TRIBUTARIES ABOVE SNAKE RIVER.

By E. H. SCHULZ, *Colonel, Corps of Engineers, United States Army.*

COLUMBIA RIVER.

Navigation.—It is possible for suitable boats properly equipped to navigate the Columbia River from the ocean to the foot of Rickey Rapids, a distance of 710 miles. In the stretch of river above the mouth of the Snake there are a large number of rapids and reefs which offer serious obstruction to free navigation on the river and the total fall is so great as to make upstream navigation very expensive.

The most serious obstructions are at Priest Rapids, Rock Island Rapids, Box Canyon, and Hell Gate. Priest Rapids and Rock Island Rapids are not navigable except for launches during the lower stages of the river and are navigable only with difficulty during the higher stages. Box Canyon is easily navigable at the lower stages of the water but its navigation is practically impossible at high water owing to the excessive swirls and eddies. It is therefore not possible to take a steamboat from the mouth of the Snake to the foot of Rickey Rapids without waiting for the proper river stages.

Kettle Falls and Rickey Rapids are a complete bar to navigation. The river above Kettle Falls is navigable to Columbia Lake in British Columbia at all stages, except at high water.

River improvement work.—In the early days some work of improvement was done on Priest Rapids and Rock Island Rapids. This consisted of blasting out obstructing bowlders and placing ring bolts to aid vessels in lining up river. The expenditures were about $70,000.

Between Wenatchee and Rickey Rapids there has been expended about $280,000 for improvement. The work consisted of the removal of obstructing reefs and rocks from the most difficult reaches. The most important places are mouth of Wenatchee River, Rocky Reach, Entiat Rapids, Methow Rapids, Foster Creek Rapids. Eagle Rapids, Box Canyon and Long Rapids, White Cap and Parson Rapids, Hell Gate, Spokane Rapids, Rogers Bar, Gifford Rapids, and Three Rock Bend. No work has been done on the Columbia above the Snake since 1917. The work done has made navigation between Wenatchee and the foot of Rickey Rapids reasonably safe.

No work of improvement has been done above Kettle Falls.

Navigation and commerce.—(*a*) Snake River to Wenatchee: No regular boats ever operated on the section from the Snake to Wenatchee.

(*b*) Wenatchee to Bridgeport: Previous to the completion of the railway up the Columbia between Wenatchee and the Okanogan, boats made daily trips between Wenatchee and Bridgeport and carried all of the freight of the Columbia and Okanogan Valleys. On completion of the railway this service was discontinued, as the railway freight rate was less than that for which the boat could operate. At high water, which is during the summer months, these boats operated up the Okanogan River as far as Riverside.

At present there is only one boat on this section of the river. It operates between Pateros and Bridgeport, a distance of about 25 miles. It is owned by the residents in the vicinity of Bridgeport, and makes such trips as may be necessary to transport

the products and supplies for the valley in the vicinity of Bridgeport. The traffic in 1920 was about 3,800 tons, valued at about $188,000, and for 1921, 11,755 tons, valued at $563,150. The traffic is generally in fruit, wheat, and miscellaneous merchandise.

(c) Bridgeport to Rickey Rapids: There is no regular boat which operates in this section. The Bridgeport boat makes a few trips each year to upriver points, for special freight.

A small boat formerly operated between Lincoln at the mouth of Spokane River and Rickey Rapids, but in a very irregular manner.

(d) River above Kettle Falls: There is no navigation on this section and there has been none for a number of years.

TRIBUTARY STREAMS.

Okanogan River.—This river enters the Columbia from the north, about 210 miles above the Snake. The work on this river consisted of rock removal, building wing dams to concentrate the flow on the bars, and placing wire cables to assist boats going upstream. A total of $41,994.58 was expended on the improvements from the mouth to Riverside. There has been no recent commerce. The improvement was dropped in 1907.

The boats which formerly operated on this river during high water ceased to operate on completion of the railway from Wenatchee up the Columbia and Okanogan Valleys.

Clark Fork.—Clark Fork enters the Columbia a short distance north of the international boundary line and about 424 miles above the Snake. It is sometimes known as Pend Oreille River below Lake Pend Oreille.

Improvement by the United States consisted in removing projecting points and submerged rocks from Box Canyon, near Metaline. The sum of $40,505.40 was expended in the improvement.

This river is navigable between Lake Pend Oreille and Albany Falls, and below the Falls to Box Canyon, a distance of 60 miles. It is also navigable between Box Canyon and Metaline Falls. During 1920, 240,000 tons of logs were floated over Albany Falls from Priest River, valued at $960,000. In addition about 60,000 tons of logs were floated in Clark Fork between Newport and Ione. The river is not now under improvement by the United States.

Lake Pend Oreille.—This lake is navigable and is used by steamboats, launches, and towboats. Logs to the extent of 80,000 tons are floated down the lake each year, and about 800 tons of general freight are transported. The steamers are used to transport passengers and freight to points on the lake. Not under improvement by the United States.

Flathead Lake, Mont.—This lake empties into Flathead River, which later enters the Clark Fork, near Plains, Mont.

The principal boat navigation is between Somers and Polson. During 1920 the commerce on this lake amounted to 204,000 tons valued at $1,100,800, of which 143,644 tons were floated timber valued at $574,576; also about 10,000 passengers were carried.

The improvement on Flathead Lake consisted in removing bowlders from Polson Bay to provide a channel 6 feet deep at low water and 100 feet wide with a turning basin at the wharves at the shore end. This work cost about $4,500.

A small amount of work removing snags from the Flathead River above the lake was also done. The improvement was completed in 1910.

The Flathead River directly below the lake is not navigable, owing to excessive falls.

Kootenai River.—This river rises in Canada, flows south into Montana and north again into Canada, entering the Columbia about 448 miles above the Snake.

Some work was done at Jennings, Mont., and upstream to the international boundary in removing the projecting points of canyon walls and obstructive rocks. The cost was $5,000. The latest report on this work is in the annual report for 1899.

Priest River, Idaho.—This is a tributary of the Pend Oreille, entering the latter at Priest River, Idaho.

The commerce is all floated logs, which are floated from points up to 50 miles above the mouth. During 1920 this commerce amounted to 310,000 tons with a value of $1,240,000.

This river is not under improvement by the United States.

Lake Coeur d'Alene and St. Joe River.—The St. Joe River is a tributary of Lake Coeur d'Alene, and the latter lake flows into Spokane River. The Spokane enters the Columbia, about 319 miles above the Snake.

Vessels operate between the towns on Lake Coeur d'Alene and the St. Joe River, a distance of about 50 miles. This line carries 30,000 passengers and 3,000 tons of freight each year.

A car ferry transports a daily train of the Oregon-Washington Railway & Navigation Co. between Anwaco and Harrison, a distance of 6 miles, and carried 75,927 passengers during 1920, also 3,000 tons of freight. Not under improvement by the United States.

GENERAL.

Navigation on the tributaries of the Columbia above the Snake, except lake navigation, is not important and probably will not increase rapidly in the near future. It is possible, however, that the Columbia River above the Okanogan will be used to a considerable extent by navigation interests to aid in developing the Columbia Valley prior to the construction of a railroad. It is impossible for vessels navigating the Columbia to compete with the railway transportation owing to the excessive cost of upstream navigation. Should the river in future be regulated by the construction of power dams and locks, it is very probable that it will be used to a large extent for the purpose of navigation.

High water in the Columbia and its tributaries occurs during the summer months. In the Columbia the highest stage is near July 1. Low water is in February. Water removed for irrigation, will, therefore, not increase the difficulties and dangers of navigation, but may even assist navigation at such places as Box Canyon and Hell Gate. An increase of the low water flow by storage would be of great assistance to navigation at all of the rapids.

A treaty exists between the United States and Great Britain, which requires that the Columbia River be kept open for navigation, therefore, should a dam be constructed at the Grand Coulee, under the Columbia Basin project, it is believed it would be necessary for the dam to include a flight of locks or other means of transfer for the accommodation of commerce. Taking the elevation of the fixed crest at 1,108, maximum high water 1,138, and extreme low water 938, there would be required five locks of 40 feet lift to overcome the total fall of about 200 feet. Each lock would be 45 feet wide by 265 feet long by 7 feet deep, and it is roughly estimated that these locks, if constructed at the same time as the dam and made a part of the same project, would cost approximately $2,600,000, which will include an entrance channel at the lower end.

It is believed that this would be a proper charge against the parties building the dam and that the United States should not be required to contribute toward the cost.

Unless the above-mentioned treaty between the United States and Great Britain is modified by agreement, it is believed that it would be necessary to complete the construction of the locks at the same time that the dam at the Coulee was constructed, but since navigation from Canada into the United States is completely obstructed above the Coulee, by Kettle Falls, it seems reasonable to suppose that there would be no objection imposed by the Canadian Government to deferring the completion of the locks at the Grand Coulee until Kettle Falls had been rendered navigable by the construction of locks.

APPENDIX B.

IRRIGATION AND POWER DEVELOPMENT AND POSSIBILITIES IN MONTANA.

By C. S. HEIDEL, *State Engineer.*

IRRIGATION.

An outline of the present and prospective irrigable areas was prepared in the State engineer's office on November 6, 1921. Since that time there has been little additional information noted on the subject, so the table is repeated here, with detailed remarks following. The location of the irrigated and irrigable tracts is shown on Plate 9.

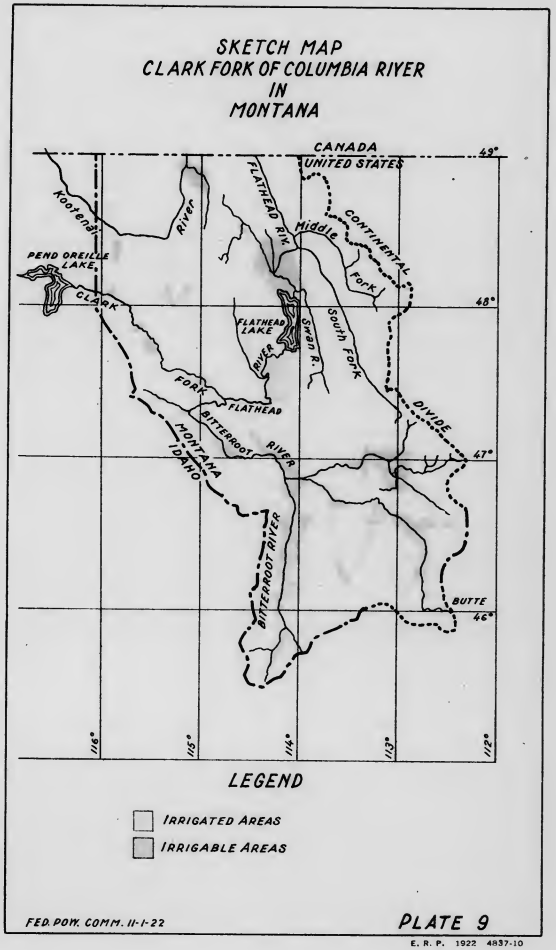
Summary of present and prospective irrigation in basin of Clark Fork in Montana.

Locality.	Acres irrigated.			Sources of information.
	Present.	15-year increase.	Possible additional.	
Above Flathead Lake	5,000	5,000	100,000	Kalispell Chamber of Commerce; checked by Buck, Lamb & Walker.
Proctor and west side of lake	1,000	.....	.....	Buck.
East side of lake	500	500	1,000	Walker.
U. S. Reclamation Service, Flathead project.	34,453	34,453	100,000	Nineteenth annual report, U. S. Reclamation Service.
Sanders County, except Flathead project.	3,220	3,000	31,800	County Surveyor Johnston.
Silver Bow County	800	.....	.....	Buck, formerly assistant city engineer, Butte.
Deer Lodge County	6,000	.....	.....	Buck.
Powell County	[1] 64,045	[1] 12,072	65,000	Do.
Granite County	[1] 31,177	[1] 7,070	30,000	Buck, more land but no water; northwest of Phillipsburg.
Missoula County, except Flathead project.	[2] 20,000	1,000	58,800	Buck suggests remote possibility 10,000 acres Swan River; Lamb says impossible.
Ravalli County	[1] 107,028	[1] 13,589	25,000	Buck.
Mineral County	1,000	.....	14,000	Do.
Total	274,223	77,284	425,600	

[1] Census figures for 10-year period 1909–1919.
[2] Difference between census 50,237 and Flathead project.

Area above Flathead Lake.—The estimates for this area were given by Mr. P. N. Bernard, secretary of the Kalispell Chamber of Commerce and are considered reasonable by Mr. Buck, Mr. Lamb, and Mr. Walker. Mr. Buck is assistant chief engineer for the public service commission and during the summer of 1920 made a study of the irrigated and irrigable lands of the State for the commission. Mr. Lamb has been district engineer of the United States Geological Survey at Helena the past 12 years. Mr. J. W. Walker is an old resident of Kalispell and the Flathead Valley, and is now State treasurer.

The county surveyor, Mr. F. P. Scott, compiled a list showing 4,122.12 acres above the lake irrigated in 1920 taken from the county records. Mr. A. L. Saunders, civil engineer, now with the State highway commission, who has a home in the Flathead



INTENTIONAL SECOND EXPOSURE

APPENDIX B.

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Silver Bow County	800	.....	.....	Buck, formerly assistant city engineer, Butte.
Deer Lodge County	6,000	.....	.....	Buck.
Powell County	[1] 64,045	[1] 12,672	65,000	Do.
Granite County	[1] 31,177	[1] 7,070	30,000	Buck, more land but no water; northwest of Phillipsburg.
Missoula County, except Flathead project.	[2] 20,000	1,000	58,800	Buck suggests remote possibility 10,000 acres Swan River; Lamb says impossible.
Ravalli County	[1] 107,028	[1] 13,589	25,000	Buck.
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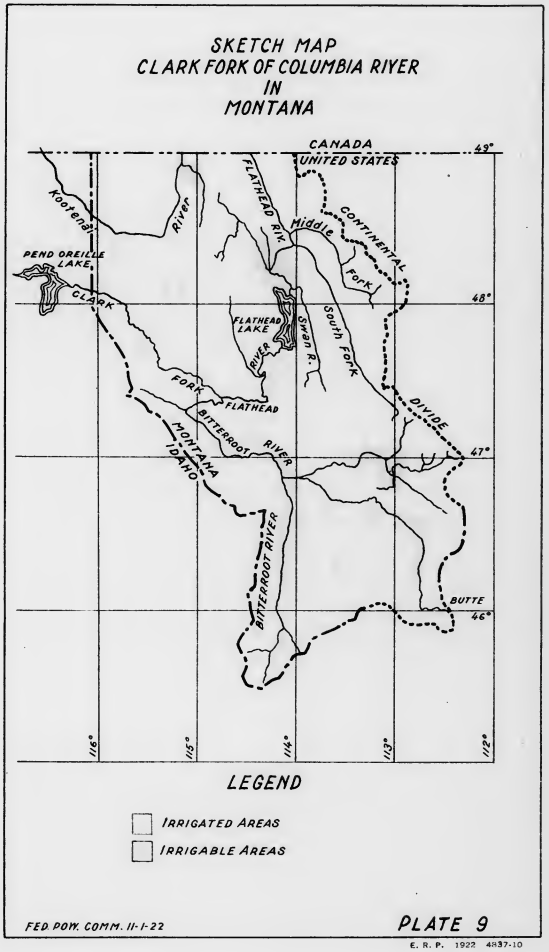


Valley southeast of Kalispell and has lived there for years, has given a list of approximately 2,000 acres additional which have been irrigated and 500 or 600 more which will be irrigated next year.

Mr. C. J. Moody, project manager United States Reclamation Service at St. Ignatius, made a reconnaissance for the Kalispell Chamber of Commerce and drew a rough sketch outlining tracts containing possible irrigable areas above the lake. These outlines embrace a total of over 150,000 acres. In addition to this Mr. F. B. Scott, county surveyor, considers portions of large additional tracts irrigable. Lillis and Bickel made a report in 1906 on irrigation possibilities above the lake. This survey included about half of the same area as covered in Mr. Moody's suggested districts, and indicates about 100 sections under canals heading on the south fork of the Flathead, the Flathead below Columbia Falls, and Whitefish River. On January 22, 1921, Mr. A. L. Jaqueth reported on the proposed Flathead irrigation district, lying southeast of Kalispell between the river and lake. The main source of supply was to be from the Stillwater with a proposed auxiliary canal from Whitefish River. The irrigable area was found to be 11,140 acres and an additional area of 12,000 acres between the Flathead and Whitefish Rivers was suggested. Mr. Moody of the Reclamation Service, made a preliminary survey for the Talley Lake irrigation district which includes 8,000 or 9,000 acres west of Stillwater River in T. 29 N., R. 22 W. This area is not included in the Lillis-Bickel report, but is covered by Mr. Moody's reconnaissance.

In claiming 100,000 additional irrigable acres, Mr. Bernard intended to be conservative, and it is believed he gave a figure which is reasonable.

West side of lake.—There is considerable land which may eventually be irrigated southwest of the lake by pumping from the lake. This has not been included because no estimates were available. Along most of the west shore both irrigable land and water supply are limited.

East side of lake.—There is not much irrigable land here and only a rough approximation could be made because of the limited development.

United States Reclamation Service, Flathead Indian project.—The twentieth annual report of the United States Reclamation Service gives the total irrigable acreage as 124,500. Because of an irrigation district being proposed along the Little Bitterroot to irrigate lands that have been withdrawn from the Flathead project, the acreage is left as estimated in the nineteenth report.

Sanders County except Flathead project.—On September 27, 1921, at Thompson Falls, County Surveyor Johnston gave the following estimates of irrigable areas in Sanders County:

Locality.	Now irrigated.	Possible additional.
Plains:		
By gravity from Cedar Creek	700	2,300
By pumping	.....	3,000
By gravity from Swamp Creek (south of river)	.....	2,000
Thompson Falls:		
East of, from Thompson River	80	2,500
Prospect Creek (south of river)	.....	1,000
South of River near Whitepine from Beaver and Little Beaver Creeks	.....	10,000
Trout Creek (south of river)	.....	2,000
Martin Creek (south of river)	.....	1,000
Swamp Creek (near Trout Creek)	.....	3,000
Noxon, from Rock Creek	.....	1,000
Bull River	2,000	2,000
Weeksville, from Buffalo Bill Creek	200	.....
Squaw Creek (north of river)	80	.....
Graves Creek (north of river)	160	.....
Heron, from Elk Creek, 10 to 12 sections of cut over bench irrigable but not enough water	.....	2,000
Total	3,220	31,800

Mr. Hillman, county agent, stated that in addition to the above the Camas Valley needs about 20,000 acres additional irrigated, but the water supply is doubtful. Plans are now being perfected (May, 1922) for hydroelectric pumping to irrigate 3,600 acres near Plains.

Silver Bow County.—The present irrigation is to a large extent for truck gardens, etc., along Silver Bow and Blacktail Creeks, and there is little chance for development.

Deer Lodge County.—The principal irrigated areas are along Warm Spring Creek, Lost Creek, and Deer Lodge River. Because water is lacking to supply present development, water is sometimes pumped over the divide from Georgetown Lake in Granite County. Some land formerly irrigated has been abandoned.

Powell County.—Mr. Buck estimated the following additional acreage irrigable:

	Acres.
Southwest of Ovando	15,000
Around Ovando	20,000
Flat around Helmville and east of Blackfoot River, including Coopers Lake irrigation district	30,000
Total	65,000

A narrow fringe may be added to the lands already irrigated along the Hellgate, Deer Lodge, and Little Blackfoot Rivers.

Granite County.—

	Acres.
Along Rock Creek	10,000
Along Flint, Hellgate, and lower Rock Creeks	20,000
Total	30,000

Mr. Earle B. Patton, county surveyor, could give no additional data.

Missoula County.—Mr. Buck considers the following areas as irrigable possibilities:

	Acres.	
On Clearwater River	4,000	
Nine Mile Prairie	3,000	
Missoula Flat	10,000	
De Smet	10,000	
Frenchtown	8,000	
Total, irrigable under present conditions		35,000
Eventually the following may be considered irrigable:		
Around Clinton, up the Clark Fork River	5,000	
Above Bonner along Blackfoot River	800	
Nine Mile Prairie, Belmont Creek to Clearwater station in addition to 3,000 above note	5,000	
Bench between Sunset Creek and Clearwater River (pump 150 feet)	5,000	
De Smet by pumping	5,000	
Hayes (a big bench)	2,000	
Stark-Alberton	1,000	
		23,800
Total		58,800

Mineral County.—

	Acres.
Miles Flat (east of Quartz)	3,000
Above Miles Flat	2,000
At St. Regis	1,000
West side bench north of Quartz	5,000
Very remote:	
Around Iron Mountain	500
Around St. Regis	500
Around Haugan-Saltese	500
East side above Quartz (near Cyr)	1,500
Total	14,000

Ravalli County.—Farming was begun in the Bitterroot Valley in 1842, and it is one of the oldest irrigated regions in the State. There are several irrigation districts as well as private ditches included in the census figures. The Bitterroot irrigation district formed to rebuild the system irrigating land under the Bitterroot Valley Irrigation Co. ditch has recently applied to the irrigation district bond commission for the certification of $1,140,000 worth of bonds.

The following figures are taken from the Montana Bulletin of the Fourteenth United States Census, 1920:

Acreage irrigated, classified by drainage basin, 1919 and 1902.

Drainage basin.	Area irrigated.			Area included in enterprises, 1920.	Area enterprises were capable of irrigating in 1920.
	1919	1902	Per cent of increase.[1]		
	Acres.	*Acres.*		*Acres.*	*Acres.*
Tributaries of Columbia River	291,966	232,451	25.6	616,080	453,588
Clark Fork and tributaries	285,984	229,851	24.4	601,657	443,864
Clark Fork direct	2,882	[2] 8,808	−67.3	14,403	4,722
Missoula River and tributaries	238,769	221,043	8.0	433,021	325,992
Missoula River direct	2,550	1,181	115.9	8,332	5,777
Hellgate River	77,381	78,139	−1.0	165,391	108,161
Bitterroot River	112,622	98,965	13.8	158,241	139,481
Big Blackfoot River	40,604	36,622	10.9	83,716	61,476
Other tributaries of Missoula River	5,612	[2] 6,136	−8.5	17,351	11,097
Flathead River	44,333	([4])	.....	154,233	113,150
Kootenai River	5,982	2,600	130.1	14,423	9,724

[1] A minus sign (−) denotes decrease. Per cent not shown when more than 1,000.
[2] Includes springs and wells and all sources in the Columbia River drainage basin, exclusive of the Missoula and Kootenai.
[3] Includes springs and wells.
[4] Not reported separately in 1902.

These indicate a considerable acreage already considered irrigable under projects, which in the natural progress of settlement will certainly be irrigated and make up a large part of the acreage classed as "possible additional" in the previous tables for Montana. This indicates that the estimates of prospective irrigated areas may be considered reasonable.

Water depletion due to irrigation in Montana.—The question of duty of water and net depletion due to irrigation is one about which nothing very definite may be said. However, after studying the available data from the Flathead project and elsewhere, I am satisfied with the allowances suggested in the studies made by the Columbia River board.

Of course I have no authority, and no other representative or officer of the State has authority under our laws to make a claim which will purport to limit the State to the use of a certain maximum amount of water for irrigation or other purposes. We can only estimate the probable maximum irrigable acreage and make an estimate of the water which may be thus consumed, and this has been done.

This maximum amount of future depletion has been estimated in the previous studies as follows:

Flathead River above lake (100,000 additional acres):	Acre-feet.
October to April (5,000 acre-feet per month) for winter storage	30,000
May	13,000
June	31,000
July	50,000
August	25,000
September	6,000
Total	160,000

Clark Fork, exclusive of Flathead River above lake and Flathead project (about 225,000 additional acres):

	Acre-feet.
May	35,000
June	85,000
July	85,000
August	60,000
September	35,000
Total	300,000

Flathead Indian project, United States Reclamation Service.—The lands irrigable under this project will be served by diversions from Crow and Mission Creeks and Jocko and Little Bitterroot Rivers, supplemented by storage in several headwater and valley reservoirs. Storage will deplete the natural flow from about October to June, diversion of natural flow from May to September, while return waters may largely offset the effect of diversions after August 1. The depletion that should be used in hydrographic studies of the river below is the difference between actual depletion and the amount which would have occurred had the entire Flathead project irrigation system been in operation. Yearly totals have been estimated as follows:

Year.	Acre-feet.	Year.	Acre feet.
1907	[1] 207,000	1916	198,000
1908	207,000	1917	163,000
1909	179,000	1918	163,000
1910	165,000	1919	67,000
1911	191,000	1920	79,000
1912	191,000	1921	[1] 100,000
1913	202,000		
1914	166,000	Mean	165,000
1915	194,000		

[1] Estimated.

The distribution of these depletion values by months will vary with the character of the run-off from year to year, and can not be closely foretold; for purposes of converting lower Clark Fork flow it may be estimated as follows:

Month.	Percentage of estimated depletion.	Average for 1908–1920 (acre-feet.)	Month.	Percentage of estimated depletion.	Average for 1908–1920 (acre-feet.)
October	3	5,000	May	20	33,000
November	3	5,000	June	30	50,000
December	3	5,000	July	15	25,000
January	3	5,000	August	5	8,000
February	3	5,000	September	0	0
March	5	8,000			
April	10	16,000	Year	100	165,000

Value of expansion.—The irrigable areas within the Columbia River Basin in Montana are comparatively limited and require but a small proportion of the total run-off of the watershed. Therefore, it seems advisable to protect these areas in their water supply and encourage development. As an indication of the value of irrigation in the Clark Fork basin the following figures for the Flathead project for 1920 from the Twentieth Annual Report of United States Reclamation Service may be quoted.

Value of irrigated crops per acre cropped	$23.85
Value of dry-farmed crops per acre cropped	5.00

These figures covered 160,000 acres of nonirrigated, and 31,349 acres of irrigated land, and clearly show the advantage to the community of having irrigated land. The records of the United States Bureau of Markets and Crop Estimates give the following figures as representing returns for the year 1920 from 11,965 farms in 31 of the Montana counties.

Crop.	Acres.	Yield.
		Bushels.
Spring wheat:		
Nonirrigated	763,062	6.15
Irrigated	31,247	21.95
Oats:		
Nonirrigated	152,370	11.30
Irrigated	19,968	33.57
Potatoes:		
Nonirrigated	1,678	58.50
Irrigated	1,284	146.00
		Tons.
Alfalfa:		
Nonirrigated	17,574	1.51
Irrigated	65,868	2.08

The above figures may not be typical of the entire State, and some of the land listed as "nonirrigated" may be low subirrigated ground. But the comparative yields indicate the value of irrigation.

POWER.

Developed power sites.—The total developed power in Clark Fork Basin in Montana is slightly in excess of 50,000 horsepower, as shown in the following table:

Developed power in Clark Fork drainage basin in Montana.

[From U. S. Geological Survey.]

Ownership.	Town and county.	Stream.	Location of power plant.	Rated capacity.		Head, forebay to tailrace.
				Water wheels.	Generators.	
				Horsepower.	*K. v. a.*	*Feet.*
Anaconda Copper Mining Co.	Phillipsburg, Granite.	Flint Creek	Sec. 36, T. 6 N., R. 14 W.	1,340	1,000	580
Granite County Power Co.	Maxville, Granite	do	Sec. 33, T. 9 N., R. 13 W.	1,000	760	61
Mission Range Power Co.	Polson, Flathead	Big Creek	Sec. 4, T. 22 N., R. 19 W.	700	640	580
Missoula Light & Water Co.	Missoula, Missoula.	Missoula River.	Sec. 20, T. 13 N., R. 18 W.	3,200	2,400	30
Mountain States Power Co.	Kalispell, Flathead.	Swan River	Sec. 30, T. 27 N., R. 19 W.	1,900	1,610	110
Saltese Electric Light & Water Co.	Saltese, Mineral	Packer Creek	Sec. 10, T. 19 N., R. 31 W.	60	80	100
Thompson Falls Power Co.	Thompson Falls, Mineral.	Clark Fork	Sec. 8, T. 21 N., R. 29 W.	43,300	37,500	50
Total				51,500	43,990	

Feasible undeveloped sites.—No complete survey of small, as well as large, undeveloped sites has been reported. Mr. E. W. Kramer, district hydroelectric engineer, United States Forest Service, Missoula, has made a study of the larger sites in Montana, which was published in the Electrical World, July 16, 1921. The following is a summary of the known sites believed to be feasible:

Power site.	Available head, in feet.	Nominal stream-flow in second-feet.		Continuous power, effective horsepower.		Authority.
		Without storage.	With storage.	Without storage.	With storage.	
Flathead River below South Fork	90	.....	.....	12,000	[1] 12,000	Kramer.
Flathead River below Polson	303	2,500	6,000	69,000	165,000	Columbia River Board.
Clark Fork, Flathead River to the Idaho line.	140	6,300	8,900	[2] 75,000	[2] 106,000	Do.
Upper Clark Fork, Fish Creek site	108	.....	.....	24,000	[1] 24,000	Kramer.
Swan River	140	.....	.....	[3] 2,500	[3] 8,000	Do.

[1] No storage available.
[2] 43,300 horsepower is now developed.
[3] 2,500 horsepower is now developed.

Power development estimated at 30,000 horsepower on the Flathead above Canyon Creek has been suggested. This would flood lands in Glacier National Park and is not considered feasible.

The above estimates of power on Flathead River and Clark Fork were made, using a storage capacity of 1,600,000 acre-feet in Flathead Lake, and a range of stage of 13 feet up to maximum of 93 feet on the Polson gauge. This, however, can not be accepted as a definite allowable range of stage until further surveys and studies have been made. Higher estimates which have been made on the basis of a 30-foot range of stage can not be considered.

The heads available on the Flathead at three of the sites listed by La Rue were added to give the 303 feet. They are No. 1, or Newell Tunnel site, 167 feet; No. 2 in NW. ¼ of sec. 22, T. 33 N., R. 1 W., 48 feet; No. 4 in S. ½ of sec. 1, T. 19 N., R. 22 W., about 40 miles below the lake outlet, 88 feet. Other sites which have been reported are not considered economically feasible.

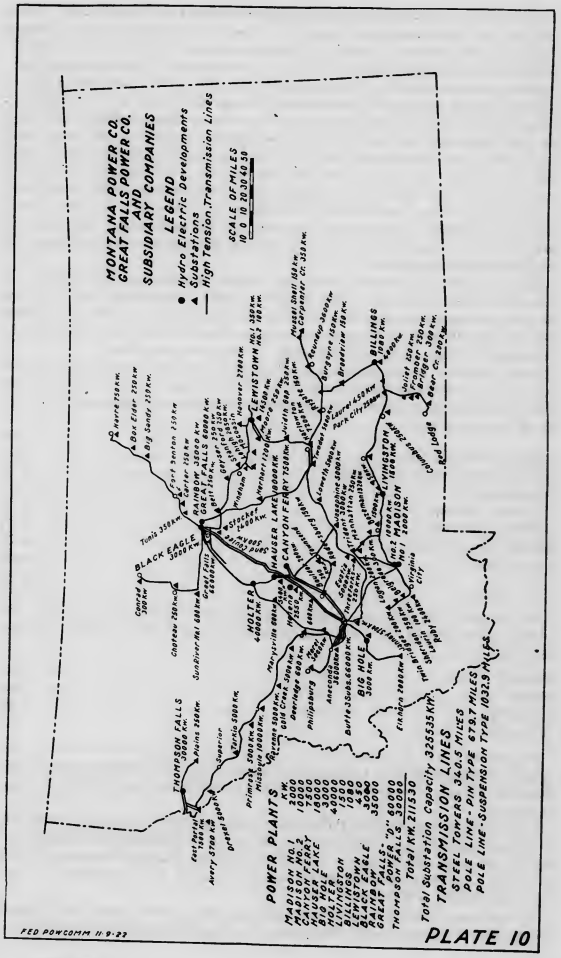
The available heads at the Thompson Falls, Donlan and Rock Island sites on Clark Fork, namely, 50, 40, and 50 feet were added to obtain the 140 feet considered above.

Some difficulty may be experienced in converting Swan Lake into a reservoir because of the investment in summer homes there.

These estimates indicate a probable total additional development on the Clark Fork and major tributaries in Montana of 270,500 horsepower.

General considerations on power.—Figures compiled by the Montana Public Service Commission in 1921 credit the entire State with 294,292 developed horsepower and 664,650 undeveloped horsepower. (Mr. Kramer's paper was used in making the compilation.) A table compiled by the State engineer's office in 1912 shows about 111,000 horsepower developed at that time. The State is sparsely settled, its area being about 147,000 square miles. The population in 1910 was 376,053 and in 1920 it was 548,889. It is reasonable to assume that the growth of population and consequent increasing power requirements will continue, and it would be unwise to handicap the rising generation by placing any great restriction on the amount of power to be developed.

Owing to the recent industrial depression some of the mining and other industries were for a time operating on a reduced basis, but conditions are now rapidly approach-



ing the former state when practically the entire developed power was in use. Therefore new power sites must be developed before power can be supplied to new industrial activities. The uses for the power will be the additional electrification of railroads, mining and metallurgy, domestic, pulp and paper mills, and other industrial uses.

There are about 90 miles of electrified track on the Butte, Anaconda & Pacific Railway and the electrified division of the Chicago, Milwaukee & St. Paul Railway extends 440 miles. The latter requires a maximum of about 40,000 horsepower or about 91 horsepower per mile. Of the 4,900 miles of railroad in the State, about 2,000 miles of the main lines of the Great Northern Railway, Northern Pacific Railway, and Chicago, Milwaukee & St. Paul Railway are not electrified. At 91 horsepower per mile this would require an additional installation of 182,000 horsepower.

The mining, milling, smelting, and refining activities consume on the average about 750,000,000 kilowatt hours annually, or nearly 115,000 horsepower. There are vast bodies of iron ore untouched and other metalliferous deposits which in time will require power for treatment.

The use of electric power for irrigation pumping is becoming more general. At the present time in Montana there are about 20,000 acres irrigated by electrically operated pumping plants and it is probable that extensive developments along this line will take place in the course of a few years. Plans are now being completed for irrigating 3,600 acres in Sanders County by hydroelectric pumping.

As an indication of the present amounts of power used for various purposes, the following percentages of the Montana Power Co.'s gross load for 1920 may be given. (This company's plants have a total generating capacity of 283,000 horsepower. See Pl. 10 for their location.)

	Per cent.
Smelting and reduction	26.29
Commercial and municipal lighting	24.00
Copper mining	14.79
Electrified railroads	12.18
Miscellaneous power	10.54
Coal and other mining	10.30
Electric heating	1.90
Total	100.00

The people of the State are accustomed to the use of a great deal of power. The annual consumption of the four leading States in kilowatt hours per person per year is as follows:

Montana	2,061
Idaho	1,361
California	1,086
Washington	883

The streets of the Montana cities are better lighted than are those in most other localities. The average per capita expenditure for street lighting in the United States is 71 cents. The average for the Western States is 80 cents while in Montana it is $1.19.

These notes are presented for the purpose of showing that Montana is now using its developed power, that it will soon require additional hydroelectric development, and that because of the limited power available in the State, reasonable safeguards should be given our power sites so our resources may ultimately be so developed as to best serve the people of the State.

The estimates of feasible power herein given are greatly below those listed as available in several Federal reports. But a careful reading of the report of the commissioner

of corporations dated March 14, 1912, which contains the earlier estimates will show that those figures are greatly in excess of commercial possibilities.

While the State is anxious for the reasonable utilization of all water resources, it must insist on protection of vested rights. While anxious to see the Flathead power developed, the possible damages of storage are so great as to warrant more thorough investigation before action is taken. Therefore, it will be considered satisfactory if a preliminary permit is granted for the purpose of protecting an applicant while making surveys, studies, and designs of Flathead development, with the understanding that the State will be fully advised of the plans and be given a further hearing before final designs are adopted.

WATER RIGHTS.

Water rights may be acquired by appropriation and beneficial use as provided in sections 7093 to 7135 of the Revised Codes of 1921.

The present status of rights to the water of any Montana stream is extremely uncertain unless there has been an adjudication by the State or Federal court. There is no limit to the amount of water that may be filed on, no provision for filing all water rights in one central office, and the county records contain duplicates and many filings of rights which have been abandoned, but still remain of record. Many rights have been perfected by use of which no record has ever been filed. This causes a confused condition which continually grows worse until the waters of a stream are finally adjudicated.

The Bitterroot and some of the other tributaries of the Clark Fork in Montana have been adjudicated, but so far as we have learned, no decree has ever been made of the Flathead River, and only one right decreed from the Clark Fork.

This was entered July 19, 1910, in file 950 of the United States District Court, and decrees 15,250 second-feet for power development and other industrial purposes to Edward Donlan and the Northwestern Development Co. This decree gives the dates of appropriation as follows:

	Second-feet.
March, 1905	1,250
January, 1906	2,000
December, 1906	5,000
June, 1909	7,000

These rights and several others are now claimed by the Montana Power Co. as applying to its Thompson Falls plant.

No provision is made in the Montana laws for storage of water within the State for use outside its boundaries. In fact, some of the residents were so alarmed at rumors of plans of the Columbia Basin survey to flood agricultural land by using Flathead Lake as a storage reservoir that the 1921 legislature passed the following resolution:

SENATE JOINT RESOLUTION NO. 1.

A Joint Resolution relating to the efforts of the State of Washington and the citizens thereof to dam the outlet of Flathead Lake in Flathead County, Mont., and hold back and impound the waters entering said lake and creating thereby a storage reservoir for the irrigation of lands in said State of Washington under what is called the Columbia Basin irrigation project.

Whereas it has been called to the attention of this assembly and members thereof, that the State of Washington and its citizens are seeking to reclaim a large area of lands entirely within said State, by a system known as the Columbia Basin irrigation project, and to secure the waters therefor, it is the purpose of the promoters of said project to construct a dam across the outlet of Flathead Lake in Flathead County, Mont., thereby raising the waters of said lake 10 to 14 feet above normal low water mark; and

Whereas in so doing, approximately 20,000 acres of the best farm lands above and around said lake will be inundated and rendered valueless and many homes on said lands and the shores of said lake destroyed; and

Whereas the city of Kalispell and other urban communities in said Flathead County are largely dependent upon the agricultural resources of that country for their existence and prosperity, and there are no compensating returns therefor, and the destruction of such farms and homes will greatly increase the burdens of taxation upon the remaining property; and

Whereas if the State of Washington and its citizens are permitted, unopposed to thus enter this State and appropriate and divert the waters thereof, it will establish a precedent which may result in inestimable injury to other communities of this State and to the State at large by depriving its citizens of the waters they need:

Now, therefore, be it resolved by the Senate of the Seventeenth Legislative Assembly of the State of Montana, the House concurring, That all the waters of this State, so long as they remain therein, are the property of this State, and its citizens, and that no other State, nor the citizens thereof, has any right to enter this State and there appropriate, impound or divert any of such waters for use outside of this State.

Be it further resolved, That the Members of Congress from this State, and all of the executive officers thereof, be and hereby are, urged and requested to make their best efforts and use all legal machinery at their command, to prevent the creation of such reservoir in said Flathead Lake and the appropriation and diversion of its waters for the use and benefit of said Columbia Basin irrigation project or any other project outside of this State.

Be it further resolved, That a copy of this resolution be sent to each Senator and Representative from this State.

Approved January 27, 1921.

Later during the session the following law was passed (ch. 220, Session Laws 1921, sec. 7135, Revised Codes of 1921):

7135. *Appropriation of waters for use out of State.*—Regulation: None of the waters in the State of Montana shall ever be appropriated, diverted, impounded, or otherwise restrained or controlled while within the State for use outside the boundaries thereof, except pursuant to a petition to and an act of the Legislative Assembly of the State of Montana permitting such action, and any appropriation, diversion, impounding, restraining, or attempted appropriation, diversion, impounding, or restraining, contrary to the provisions of this act shall be null and void; and all officers, agents, agencies and employees of the State are prohibited from knowingly permitting, aiding, or assisting in any manner such unauthorized appropriation, diversion, impounding, or other restraint. It shall be unlawful for any person, persons, or corporation, directly or indirectly, personally or through agents, officers, or employees, either to attempt to so appropriate, divert, impound, or otherwise restrain or control any of the waters within the boundaries of this State for use outside thereof, except in accordance with the terms of this act.

It will therefore be necessary before any steps can be taken to store Flathead water for use outside the State, first to secure the passage of a law authorizing such storage. It will also be necessary to give due consideration to the decreed water right at Thompson Falls on the Clark Fork.

In conclusion it should be stated that the State of Montana considers it a privilege to be permitted and is willing and anxious to cooperate with the Federal Power Commission and the States of Idaho and Washington in making studies which will aid in solving our water utilization problems. We believe that the benefits of irrigation are so great that all possible irrigation development should be protected, because of the comparatively limited irrigable area in the Clark Fork Basin in our State. We believe also, in view of the rapidly increasing demands for power and the limited possibilities of power development in Montana, that the power possibilities of the State should be given serious consideration. It should be remembered, however, that while pleased to cooperate in the studies, no action by any State department or officer can be construed as binding on the State in disposing of or granting to any interest rights to the use of water or other resources without full compliance with the laws of the State.

APPENDIX C.

IRRIGATION AND POWER DEVELOPMENT AND POSSIBILITIES IN IDAHO.

By W. G. SWENDSEN, *Commissioner of Reclamation.*

Idaho deeply appreciates the broad policy of the Federal Power Commission in affording the State an opportunity to participate in the general planning of works looking toward the true conservation and proper economic development of its great water resource, and desires to assure a hearty cooperation with its border States and with the Federal Government in carrying into effect the recommendations contained in the report of the Columbia River board; provided, of course, that the report is adopted in its entirety and Idaho thereby, with other States, accorded a protection adequate to the needs of its future development.

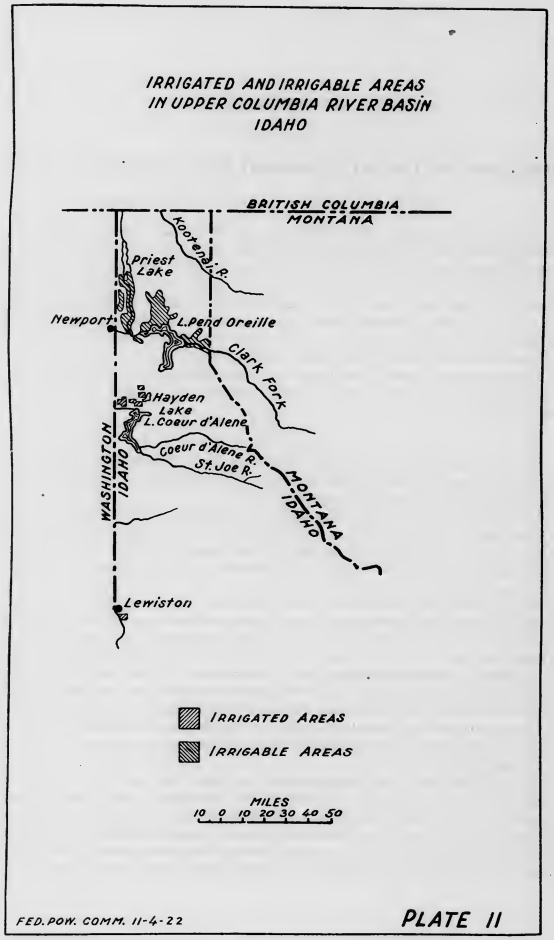
Pursuant to the request of the board for a statement from each of the States, the following general outline of Idaho's conditions and requirements is respectfully submitted:

IRRIGATION.

The exact area under irrigation in Idaho from Clark's Fork drainage basin water supply is not known, but is so small as to be rather insignificant. Existing rights for this purpose must, of course, be respected.

The potential irrigation possibility in Clark's Fork drainage basin in Idaho can only be estimated. From general data, furnished in part by representatives of the Sand Point Chamber of Commerce, it appears that approximately 150,000 acres of agricultural land are susceptible of irrigation from this source of water supply. (See Pl. 11) This area is under present conditions partly given over to forest, partly to cut-over stump land and agricultural uses without irrigation. The precipitation in the area generally affords sufficient moisture for the growing of limited crops, but irrigation is essential to maximum production and proper diversification and rotation of crops. Considering the size of this drainage basin in Idaho, the foregoing irrigable area might be regarded as small and therefore of little consequence, but as a matter of fact the development and protection of all of the potential agricultural resources in north Idaho is extremely important, since it is quite certain that all of the area which can be successfully tilled will be required to supply local demands for agricultural products when the lumbering, mining, and other basic industries of this part of the State are fully developed.

On account of these conditions, the State is extremely anxious that no permanent rights to the use of its water supply shall accrue which would tend to retard or ultimately prevent the maximum irrigation development within its borders. There is a dearth of data as to the duty of water in this area. Annual precipitation is relatively heavy, but amounts to little or nothing during the growing season. Until some dependable estimates can be made, 2 acre-feet should be reserved for this area.



POWER.

There is now developed in the upper Columbia River drainage basin in northern Idaho a total of 17,200 horsepower as shown in the following table:

Developed water power in upper Columbia River drainage basin in Idaho.

[From U. S. Geological Survey.]

Ownership.	Town and county.	Stream.	Location of power plant.	Rated capacity.		Head.
				Water wheels.	Generators.	
				Horsepower.	*Kva.*	*Feet.*
Bonner Water & Light Co.	Boundary County.	Myrtle Creek..	Secs. 19 and 20, T. 62 N., R. 1 E.	250	150	250
Canyon Light & Water Co.	Mace, Shoshone County.	Canyon Creek.	T. 48 N., R. 5 E.....	160	100	.....
Northwest Light & Water Co.	Wallace, Shoshone County.	Placer Creek..	Sec. 34, T. 48 N., R. 4 E.	345	300	310
Mullen Light Co., Ltd.	Mullen, Shoshone County.	Mill Creek.....	Sec. 34, T. 48 N., R. 5 E.	65	50	250
Washington Water Power Co.	Post Falls, Kootenai County.	Spokane River	Sec. 4, T. 50 N., R. 5 W.	16,300	[1] 11,250	52
Montana Iowa Copper Co.	Shoshone County.	Manhattan Creek.	Sec. 18, T. 47 N., R. 7 E.	75	.....	300
Total.....	.....	.....	.....	17,200	11,850	.....

[1] Kilowatts.

Only 410 horsepower out of a total of 17,200 is located in the Clark Fork Basin. Like the accrued irrigation rights present power rights must be respected.

The most important undeveloped power site on Clark Fork in Idaho is Cabinet Gorge located just below the Montana-Idaho State line and above Lake Pend Oreille. A head of 77 feet can be developed without interfering with the Northern Pacific tracks. The width of river is 175 feet at low water and only slightly greater at the proposed flow line. While no data is available in regard to depth of water this is regarded as a power site of exceptional value. With the nominal flow without storage 43,000 continuous horsepower can be developed, while with Flathead Lake utilized for Flathead Lake power this is increased to 59,000 horsepower.

Priest River has a fall of 388 feet between Priest Lake and its mouth, a distance by river of nearly 40 miles. A regulated flow of 1,100 second-feet can be secured with a 15-foot range of stage on Priest Lake. Surveys have been made for a power site which would take water from a Priest River storage dam and secure 125-foot head with a total length of conduit of about 5½ miles. A lower proposed site with dam about 6 miles above the mouth and a conduit about 2½ miles long would render available about 60 feet. Other portions of the river are not well adapted for power development on account of the low gradient. If a total of 230 feet or 60 per cent of the gross head can be utilized the total potential power is 23,000 horsepower.

The amount of possible power in this watershed in Idaho depends very largely upon which plan is adopted for the Columbia Basin irrigation project. In the event a gravity plan, as tentatively outlined in the board's report, is employed, approximately 23,000 horsepower on Priest River is destroyed and Idaho's ultimate resource and taxable wealth therefore materially reduced. Because of this condition, however, the State has no desire to stand in the way of the Columbia River project, but on the contrary, is anxious to aid in its development. Idaho fully realizes that the irrigation of Columbia Basin lands, even though situated in another State, will result in many direct and indirect benefits to the State and the Nation. On the other hand, it is in

the interest of Idaho that Columbia Basin pumping project be adopted, provided its feasibility is found to compare favorably with the gravity scheme.

Little is known regarding the potential power on the smaller and less important tributary streams in Idaho, but such sites as exist should be protected and their future development permitted in order to accommodate the needs of the local commercial industries, at least until such time as base power lines are constructed, from which power may be had to meet local demands. Except in cases where these tributary streams may be regulated by small storage, development of power thereon can not interfere with the major power development in the watershed and in the event such storage reservoirs are constructed, it is highly probable that they will coordinate with the main scheme and tend toward equalization of flow.

OTHER COMMERCIAL INDUSTRIES.

Lumbering has heretofore constituted one of the most important industries in north Idaho, and it is very important that due and proper regard be given to protection of this resource. In connection with the construction of dams, fluctuation of lake levels, and other changes of existing conditions, the importance of providing passages for logs through or over any dams constructed, and commerce on the lakes essential to this industry, must be given adequate consideration.

Water transportation on Pend Oreille and Priest Lakes, in so far as it is now or may in the future be carried on, should be safeguarded in the interest of the State and its industries.

Idaho has come to realize the necessity of fully considering the ultimate use of its water resource in connection with the granting of rights of way over State and public lands, to the end that railroads, highways, and other improvements shall not be so situated as to seriously interfere with future hydraulic development, and the State will appreciate Federal cooperation along this line.

GENERAL.

No inconsiderable value has accrued to Idaho from the use of the beautiful lakes of Pend Oreille and Priest for recreation and resort purposes, and due consideration should be given to this matter in connection with this proposed development, to the end that in so far as possible the natural scenic beauty of the landscape be retained and the least possible damage result to personal and public resort and summer home property.

In the design and construction of structures, due regard should be given to artistic effect and plans in harmony with the landscape in so far as consistent with cost and other conditions should be adopted.

The public and other improvements of cities and villages situated on the river or lake shores, such as culinary water supply, drainage, etc., should be duly regarded and protected.

LEGAL FEATURES.

Under Idaho's laws and constitution, the State has and retains control of all water within its borders and any and all rights to the use thereof are only granted conditioned upon continued beneficial use.

The priority of rights as between appropriators is governed by the doctrine of "first in time, first in right."

Rights to use water may be established in either of two ways:

First, under the constitution, an appropriator may, by the construction of works and the subsequent diversion and beneficial use of water, acquire a prescriptive right. Such a right, however, can not be recognized by an administrative officer charged with the responsibility of distribution until it shall first have been made of record by decree of court, or by employing the provisions of the permit law.

Second, the right to the use of water may be acquired by complying with the statute known as the permit law. This process requires the filing of an application for permit in the State department of reclamation, in such form and accompanied by such data as the said department may prescribe. Such a permit does not necessarily represent a water right, but after all of the requirements of the permit law are fulfilled a permit may ripen into a right, which is evidenced in a license issued by the State department of reclamation.

The basic requirements of the permit law are as follows: Within two and one-half years after the date of approval of any application for permit, one-fifth of the work contemplated thereunder must be completed, and within five years of such date the entire works necessary to diversion and application to beneficial use must have been completed, and proof of such completion made as provided by law. Within 11 years after the date of the approval of the permit, proof of application of the water to beneficial use is required, if the original date of priority is to be maintained.

The process of obtaining a right under the permit law has the advantage over the constitutional or prescriptive right method in that what has been defined by the courts as the "doctrine of relation" is invoked in the case of the permit right, and the date of priority relates back to the date of filing the application in the department of reclamation; whereas, under the constitutional method the best date of priority that can be secured is the date of first application to beneficial use.

It should be kept clearly in mind that there is no provision of law under which the State or any of its officers can reserve water for any particular use. When an application for permit is filed which contemplates the use of water within the State, it is mandatory that the application be approved and the permit issued, provided it is in proper form and accompanied by the required data. The law relating to appropriation of water for use in other States has not been interpreted by any court, but it is reasonable to assume that under its provisions the State administrative office can impose conditions in any permit granted which will adequately protect the future requirements or needs of the State for use of any or all of the water in question.

A part of the right of way or land essential to use of Priest and Pend Oreille Lakes for storing water is in State ownership. The State board of land commissioners is vested with authority to dispose of State land for right of way or other purposes, but may in its discretion refuse to offer any land for sale, and by reason of this condition the State is in a position to exercise a limited control over the appropriation of water for storage purposes and thus is able to protect its rights and to materially aid in carrying out a proper plan of development of the Clark's Fork water resource.

Chapter 218 of the Idaho Compiled Statutes provides for appropriation of water in the State of Idaho for use in other States. The State of Washington having by the provision of section 3, chapter 103, 1921 Session Laws, adopted "reciprocal legislation," may avail itself of the foregoing Idaho law.

In the matter of appropriating and utilizing water in Idaho in connection with this proposed development, the State deems it important that its laws be complied with, and Federal permits for power sites should contain appropriate provisions regarding this matter. In this connection, attention is directed to the statutory provision which requires that all plans for hydraulic development, particularly the construction of dams, be filed with and approved by the State in advance of actual construction.

The State's participation in this report, and the approval thereof by its representative, shall not be construed as limiting or affecting in any manner the rights it has in ownership or control of its water supply or any property rights it may have growing out of land or property ownership.

APPENDIX D.

PART 1.

IRRIGATION AND POWER DEVELOPMENT AND POSSIBILITIES IN WASHINGTON.

By MARVIN CHASE, *Supervisor, Division of Water Resources.*

We submit herein a summary of the data which have been presented to the Columbia River Board relative to the State's right to control the use of waters within its boundaries, subject only to the Federal Government's supervision over navigable waters; the relative needs for irrigation and power development in the State; and the especial problems presented by the Columbia Basin irrigation project.

Reference is made to the list of the several briefs and tabulations which have heretofore been submitted to you, appended hereto. You also have the 1920 report of the Columbia Basin Survey Commission, General Goethals's report, and the briefs submitted by the chief engineer of the Columbia Basin Survey.

THE STATE'S RIGHT OF CONTROL.

It is now the well-established doctrine in the United States that each State in its sovereign capacity controls the waters within its boundaries, subject only to the Federal Government's control of navigation and its rights as owner of riparian public lands. This doctrine is the result of various important acts of Congress recognizing the arid-region doctrine of appropriation, State laws and customs, and the interpretation given such laws by the State and Federal courts, including the Supreme Court of the United States. The principal acts upon which this is based are the act of 1866 recognizing appropriations based upon local customs and laws and decisions of courts; the act of 1870 making all patents subject to vested rights; the desert-land act of 1877; the act of 1891 granting rights of way for irrigation ditches over public lands; the Carey Act of 1894; and the national reclamation act of 1902. The latter act, for instance, fully recognizes the State's control in the following clear terms:

"That nothing in this act shall be construed as affecting or intending to affect or to in any way interfere with the laws of any State or Territory relating to the control, appropriation, use, or distribution of water used in irrigation or any vested rights acquired thereunder; and the Secretary of the Interior, in carrying out the provisions of this act, shall proceed in conformity with such laws."

In view of this recognition of the State's control, the Washington State Legislature in 1905, to assist the Federal Reclamation Service, passed an act setting aside certain stream systems for the benefit of certain Federal projects. The United States Reclamation Service has always complied with the State law in respect to appropriations, and both the State and Federal Governments have worked harmoniously together.

The State of Washington, by constitutional provisions and repeated legislation, has exercised its control over the waters within the State. This legislation culminated in the water code of 1917, a comprehensive enactment by the State for the complete control and regulation of the diversion and use of waters within the State. Of this code the Supreme Court of Washington has said (West Side Irr. Co. *v.* Chase, 115 Wash. 150):

"This code appears to be broad enough to include almost any conceivable right with reference to irrigation and to provide an inexpensive and ready manner of settling all disputes concerning such matters."

The State of Washington, in section 3, chapter 103, Laws of 1921, authorizes the supervisor of hydraulics to grant permits for the diversion of the waters within the State of Washington for use outside of the State, provided that the State within which the waters are to be used has a similar provision whereby waters within that State may be diverted for use within the State of Washington. Several States have such reciprocal legislation, including the States of Oregon and Idaho, and other States, no doubt, will from time to time extend the same comity.

By the acts of Congress referred to and other acts supplemental to and amendatory of them, by the oft-repeated decisions of the highest judicial tribunals of the United States affirming the State's authority in clear and unequivocal terms, and by the State's thorough legislation, there can be no question that the State of Washington has full control over the waters within its borders. Under its exchange of reciprocal legislation the State also has the undoubted authority to make appropriations of water within other States, in accordance with their regulations, for use within this State.

Paramount to the foregoing indirect recognition of State control of water resources is the statement contained in the act creating the Federal Power Commission (sec. 9, b) requiring applicants to present "satisfactory evidence that the applicant has complied with the requirements of the laws of the State or States" relative to location and appropriation of water rights, etc. The act under which this Columbia River Board has its existence therefore directly admits the sovereign power of the State over its waters.

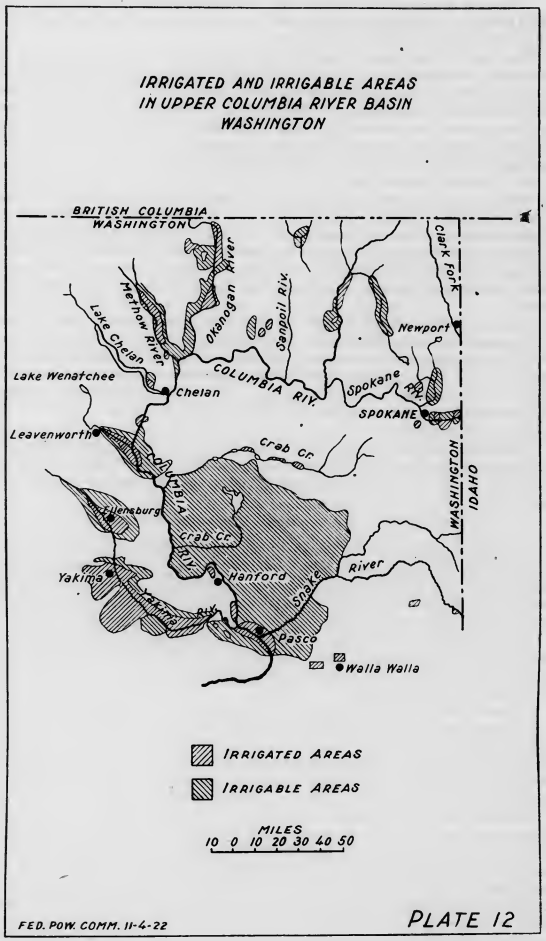
The State of Washington is within its rights in adopting the principle that at least within the arid portion of the State river control and diversion of water must be primarily for the use and benefit of agriculture and secondarily for the development of power.

RELATIVE NEEDS FOR IRRIGATION AND POWER DEVELOPMENT.

A positive need exists in this State for immediate development of additional agricultural land. Within the area being considered by this board reclamation by irrigation is the only method for increasing the productive area. The second biennial report of the State hydraulic engineer to the Governor of Washington shows there are 538,000 acres irrigated in this State, with 2,526,000 acres awaiting irrigation. Eighty-two and four-tenths per cent of the irrigable area of this State is now arid and can never be reclaimed unless the right to use of water for irrigation is prior to all other rights. Capital can not be interested in development of land which is dependent upon uncertain water supply.

The accompanying tables show that at present only about 380,000 acre-feet of water are diverted from the Columbia River and its tributaries in this State for the irrigation of 95,000 acres (see Pl. 12), and that 6,710,690 acre-feet will need to be diverted to meet the known requirements of additional lands which must soon be irrigated. No power development is conceivable which could rival in importance the agricultural prosperity which this amount of water would create upon the lands.

The reservation of any part of this water for power is not necessary, since there exists in the State an enormous potential water power far in excess of any anticipated market. On February 25, 1922, the United States Geological Survey issued a statement showing that 5,000,000 minimum and 8,600,000 maximum horsepower can be generated from the streams of this State, with from eight to sixteen million additional horsepower in the three neighboring States. Bearing in mind that the total development at Niagara Falls recently approximated but 1,000,000 horsepower, it is evident that the four Northwest States will have sufficient power for centuries to come. No



acre of land should ever be left arid in order to reserve the water for power use. The land is very small in amount and will soon all be needed, while the power is practically unlimited in quantity and may never all be required.

COLUMBIA BASIN PROBLEMS.

The essential data concerning the water supply for the Columbia Basin irrigation project are briefly stated as follows:

(1) *Water duty.*—The Columbia Basin lands were cruised section by section by men formerly with the United States Reclamation Service. The water required to properly irrigate each section or smaller subdivision was ascertained and the net total delivery on the land was found by adding the needs of the 1,753,000 acres. The needs vary from 24 to over 60 acre-inches per acre, with an average over all of 33 acre-inches.

(2) *Water losses.*—The losses estimated in both main and distributing canals check very closely with the actually measured losses on very large areas of similar character. Seepage, evaporation, and regulation wastage approximate 20 per cent of the gross diversion. This figure agrees with the long experience in southern Idaho, California, and the Yakima Valley.

(3) *Seasonal use of water.*—Based upon the later records from the Yakima project, it is advisable to modify the monthly demand as published in the 1920 report to that tabulated in letter to your chairman, February 18, 1922. The latter table plats a slightly flatter curve of water demand than the recent Sunnyside figures.

The Columbia Basin area will be devoted mainly to diversified farming. The United States Reclamation Service official publication, Reclamation Record (November, 1918, p. 525), states that with proper diversification of crops "the operating force can keep their canals carrying an approximately uniform flow of water all the time." Reference is made to the best use of water by increasing the May and June demand under conditions which are like those in the Columbia Basin. With such authoritative backing, we are clearly correct in adopting the flatter demand schedule.

(4) *Gross water required.*—Changing the rate of demand does not change the total net requirement nor the total gross diversion of water. A larger proportion, however, of the diversion can be taken from the river flow during the flood season and a less storage is required. This has been sufficiently analyzed in the studies previously submitted, which show that the proposed storage is more than sufficient for the maximum Columbia Basin development.

(5) *Water supply available.*—Until publication is made by the Federal Government of river discharge records showing a material change from the quantities heretofore published, it is not necessary to enter into a recomputation of the exact quantity of storage required to regulate the flow of either the Flathead or Pend Oreille (Clarks Fork) Rivers to meet the irrigation demand. Even under the most adverse conditions of irregular monthly flow and lowest annual run-off the water supply is more than ample to meet all demands, and excess storage capacity is cheaply available. Since neither the irrigation nor the power demand can be exactly known at this time, and the first reservoir will have had several years' service before the maximum of all demands can arise, it will be easy at that time to determine exactly what amount of storage should be provided in the second reservoir. There is so much excess of water and such a low cost per acre-foot of storage that any desired adjustment can be readily made when necessary. Academic discussion prior to that time is futile.

(6) *Economic effect of storage.*—Storage in Flathead Lake to elevation 2,893 will flood an area 14,000 acres greater than the low-water area. Pend Oreille Lake at 2,065 floods 5,700 acres more than at low water. The Columbia Basin estimated cost includes a very liberal allowance for the purchase of all these lands, although but a small portion of them is actually damaged, as these areas are naturally flooded at frequent

intervals. Some agricultural production is made from the higher portion of the area in years when the lakes do not reach the higher stages. This production may be lost under the proposed plan. Offset to this is the reclamation of nearly 2,000,000 acres from absolute desert to a state of highest cultivation. This phase of the situation has been fully discussed in the brief submitted on behalf of the State of Washington at the hearing before your board on March 27 and 28 of this year.

(7) *Cooperation with power developments.*—At the hearing just referred to, it was stated by the representatives of the various power interests, as well as by the Columbia Basin survey, that there is no conflict between the several plans for using the water of the lakes. Further, it was then shown that the studies already before your board indicated the fact that the water stored in Flathead Lake for irrigation use could be released so as to greatly benefit the power plants along the stream and still be available for use by storage in Pend Oreille Lake and diversion to the basin lands. Correspondence with all the larger power companies in the Northwest proves the statement that the power so made available is vastly greater than any possible market for many years to come. Commencement of use of the water for irrigation would be coincident with the completion of the distributing canals.

(8) *Goethals's report.*—Since the presentation to you of the various data contained in the several reports and briefs referred to, a report has been received from Maj. Gen. George W. Goethals, who was engaged by the State of Washington to conduct a field examination and also review the studies previously made upon the Columbia basin project. In conformity with section 73 of chapter 7 of the Session Laws of 1921, this report was adopted by the State of Washington. A copy has been transmitted to your chairman and sustains in every particular the conclusions reached by the State commission. He particularly went into the question of water supply, storage, and general feasibility of the construction proposed. He also investigated the power question, both generation and marketing. His findings are so nearly identical with the statements herein presented that we are justified in referring to such eminent authority in engineering as "amicus curiæ." We believe that your honorable board will find considerable satisfaction in knowing that a decision by you in conformity with the claims of the State of Washington and the needs of Columbia Basin project will be publicly approved and ably defended.

(9) *Davis's report.*—Another report of great importance is that of Director Arthur P. Davis, of the United States Reclamation Service, on the problems of Imperial Valley and vicinity, filed with the Secretary of the Interior on last February 4. After discussing the particular rule which should govern the various reaches of the river, he makes the very broad, but correct, statement: "In general, where irrigation interests are practicable, they should be given preference over power interests, * * *."

(10) With the chief authority of the Federal Government in reclamation matters and the leading engineer upon Government work outside of reclamation work, both in agreement that the use of water for irrigation is of greater importance than its use for power, our claim to that effect seems well supported.

(11) *Conclusion.*—The State of Washington claims the right to proceed, in accordance with the laws of the several States concerned and the Federal Government, to acquire and perfect water diversion and storage rights and to control such stored waters for the primary benefit of the lands to be reclaimed and secondarily for the benefit of such power plants as may now or hereafter exist along the streams below such storage.

PART 2.

STUDY OF WATER SUPPLY ENTERING FLATHEAD AND PEND OREILLE LAKES.

LOW WATER SEASON APRIL, 1919, TO MARCH, 1920.

By MARVIN CHASE, *Supervisor, Division of Water Resources.*

There are two methods of determining the inflow of Lake Pend Oreille, both being alike in that the algebraic difference of storage in the lake is applied to the gauged outflow of the lake. In the first method the lake elevations taken at Sandpoint, Idaho, at the end of each month, and the change in elevation during each month applied to a curve which correlates elevations and storage capacity of the lake, shows the increase and decrease of stored water in the lake during the corresponding period. The outflow for the month corrected by this increase or decrease of storage gives the inflow for the month.

In the second method the mean flow computed from the daily river gaugings at Newport or Metaline Falls is referred to a curve which correlates the lake elevations and the river discharge for simultaneous readings, and the mean elevation of the lake surface corresponding to the mean outflow for the period is thus found. The mean lake elevations month by month applied to the curve showing relationship of gauge height and storage capacity, as in the first case, gives a figure representing the change in lake content. This change is not as between the ends of two consecutive months, but is the change between the mean content of one month and the mean content of the following month. This correction applied to the total outflow for the month gives the total inflow, but is in error in applying the mean difference between the two months instead of applying the net difference for the individual month under consideration. Over a period of many readings the results are practically the same, but for any individual month a considerable difference may be shown.

The second method was used in arriving at the unregulated lake elevation shown in column 3 of the reservoir regulation on pages 62 to 68 of the Columbia Basin report.[1] For the purpose of ascertaining the average lake elevation month by month, the second method gives a better result than is found by averaging the more or less irregular weekly readings made on the Sandpoint Lake elevation gauge. For the purpose of determining the actual inflow into the lake and the amount in storage after a dam is placed at the outlet, the second method is inferior to the first. The differences, however, are small and are at their maximum at times when the river is in flood and a large amount of water is being wasted downstream, and are therefore immaterial for the purpose of the Columbia Basin gravity supply study or of any reasonable commercial power development.

From the monthly inflow thus arrived at, a deduction was made for probable future irrigation demand from the water-shed above Pend Oreille Lake, estimated as near as possible from information made available for the Columbia River board. Lacking information to the contrary, I am unable to dispute these figures.

The values thus arrived at would hold for the net available flow past Newport, but for the fact that storage must also be had from Flathead Lake, and in order to properly study the available supply, outflow at Polson was reduced to inflow based upon gaugings at Polson and Flathead Lake stages as obtained by the United States Geological Survey. Plus and minus corrections were, therefore, made to readings at Polson as dictated by lake stages at beginning of each month and monthly values arrived at for inflow to Flathead Lake. The Columbia Basin capacity curve for Flathead Lake was used for this purpose.

[1] "The Columbia Basin Irrigation Project," a report by the Columbia Basin survey commission, State of Washington, 1920.

From values thus arrived at, deductions were made for probable future irrigation demand above Flathead Lake, based upon information previously referred to.

Inasmuch as Flathead River is a tributary to waters entering Lake Pend Oreille, the plus or minus corrections at Polson were also applied to net values previously arrived at for run-off at Newport.

This twofold correction for natural storage in Flathead and Pend Oreille Lakes has the effect of materially increasing the early summer run-off and correspondingly decreasing that of the late months.

One of the principal objects of this study being the determination of power possibilities of the Pend Oreille River at Metaline Falls after the Columbia Basin demand is satisfied, it is desirable to obtain the regulated run-off at that point, which was done by adding the difference between gauged run-off at Metaline Falls and the partly gauged and partly estimated flow at Newport to the completed regulated run-off at the latter point. In doing this the effect of any inaccuracy in gauging and estimates at Newport has been entirely eliminated.

Tables Nos. 1 and 2A show values and how they have been arrived at. Table No. 2B shows the necessary storage required for the Columbia Basin alone and for various power demands at Metaline Falls. It is intended to provide this storage in Pend Oreille, Flathead, and possibly Priest Lakes.

It is intended to extend this study to determine what primary power may be available in Flathead River under the several alternatives, i. e., different power demands at Metaline Falls.

Tables 3A and 3B show discharge available for power in Flathead and Pend Oreille Rivers, respectively, under different schemes of operation and with a given amount of storage, viz, 1,560,000 acre-feet in Flathead Lake and 1,425,000 acre-feet in Pend Oreille and Priest Lakes. Irrigation demands in Montana, as well as full Columbia Basin demand, are being satisfied.

Table 4A shows the present irrigation demand for lands irrigated from the Columbia River and tributaries.

Table 4B shows all estimated future irrigation demands in the State of Washington from the Columbia River and its tributaries above Priest Rapids.

Table 5 shows the estimated discharge of the Columbia River as regulated by 2,985,000 acre-feet of storage, for each successive stream, the estimated irrigation demand on such stream and the remaining flow. In this table it has been assumed that the minimum flow of the Pend Oreille River at Metaline Falls would be regulated to 4,000 second-feet, and that irrigation demands in Montana and full Columbia River requirements have been satisfied.

The hydrographs, submitted separately, show graphically some results of studies in the tables as fully explained in the titles. The large hydrograph shows discharge in acre-feet of Pend Oreille River at Newport over the period 1903 to 1920, inclusive; also irrigation demands in Montana and full Columbia Basin demand.

TABLE 1.—*Reduction of outflow to inflow in Pend Oreille and Flathead Lakes, based upon flow at Newport as estimated by Columbia Basin commission and U. S. Geological Survey gaugings at Flathead River near Polson and gauge readings on both lakes; also showing estimated future irrigation demands and remaining inflows.*

PEND OREILLE LAKE.

[Values in acre-feet.]

	Outflow Columbia Basin report.	Gauge height, end of month.	Correction outflow to inflow (+) or (−)	Inflow.	Future irrigation demand above lake.	Remaining inflow.
1919-20.						
April	1,279,800	2,051.6 2,054.1	+205,000	1,484,800	11,700	1,473,100
May	3,131,100	2,059.7	+460,000	3,591,100	57,700	3,533,400
June	4,001,400	2,062.1	+200,000	4,201,400	173,100	4,028,300
July	1,853,300	2,056.0	−505,000	1,348,300	158,100	1,190,200
August	792,000	2,051.9	−335,000	457,000	88,700	368,300
September	460,300	2,050.7	−95,000	365,300	44,300	321,200
October	399,700	2,050.5	−15,000	384,700	7,000	377,700
November	398,700	2,050.5	.....	398,700[3]	7,000	391,700
December	313,500	2,050.6	+10,000	323,500	7,000	316,500
January	387,600	2,051.1	+40,000	427,600	7,000	420,600
February	463,200	2,050.6	−40,000	413,200	7,000	406,200
March	517,700	2,051.2	+45,000	562,700	8,400	554,300
Total	13,988,500	.....	−30,000	13,958,500	577,000	13,381,500

FLATHEAD LAKE.

	Outflow from Flathead Lake at Polson.	Gauge height, beginning of month.	Correction outflow to inflow (+) or (−).	Inflow.	Future irrigation demand above lake.	Remaining inflow.
1919-20.						
April	318,300	2,879.3	+480,000	798,300	5,000	793,300
May	1,531,100	2,883.0	+760,000	2,291,100	16,000	2,275,100
June	2,076,500	2,888.8	−510,000	1,566,500	48,000	1,518,500
July	891,600	2,884.9	−493,000	398,600	43,000	355,600
August	335,100	2,881.1	−145,000	190,100	12,000	178,100
September	182,100	2,880.0	−105,000	77,100	6,000	71,100
October	141,400	2,879.2	−51,000	90,400	5,000	85,400
November	132,100	2,878.8	+12,000	144,100	5,000	139,100
December	102,700	2,878.9	−12,000	90,700	5,000	85,700
January	95,900	2,878.8	+12,000	107,900	5,000	102,900
February	92,000	2,878.9	.....	92,000	5,000	87,000
March	92,800	[1] 2,878.9 [2] 2,878.9	.....	92,800	5,000	87,800
Total	5,991,600	−0.4	−52,000	5,939,600	160,000	5,779,600

[1] First. [2] Last.

TABLE 2A.—*Available run-offs at Newport and Metaline Falls and storage capacities required for different power demands.*

[Values in acre-feet.]

	Pend Oreille Lake.			Pend Oreille at Metaline Falls.		Columbia Basin project.	
	Net inflow (see Table No. 1).	Corrections due to difference between outflow and inflow, Flathead Lake.	Available inflow.	Inflow between Newport and Metaline Falls.	Corrected flow at Metaline Falls.	Demand.	Draft from storage.
1919-20.							
April	1,473,100	+480,000	1,953,100	130,300	2,083,400	560,600	.....
May	3,533,400	+760,000	4,293,400	4,900	4,298,300	1,152,200	.....
June	4,028,300	−510,000	3,518,300	26,800	3,545,100	1,152,200	.....
July	1,190,200	−493,000	697,200	95,900	793,100	1,152,200	.....
August	368,300	−145,000	223,300	44,300	267,600	1,089,900	455,000
September	321,200	−105,000	216,200	35,700	251,900	685,100	466,900
October	377,700	−51,000	326,700	16,000	342,700	436,000	109,300
November	391,700	+12,000	403,700	23,200	426,900	.....	.....
December	316,500	−12,000	304,500	22,800	327,300	.....	.....
January	420,600	+12,000	432,600	30,700	463,300	.....	.....
February	406,200	.....	406,200	43,400	449,600	.....	.....
March	554,300	.....	554,300	.....	554,300	.....	.....
Total	13,381,500	−52,000	13,329,500	474,000	13,803,500	.....	1,899,800

TABLE 2B.—*Columbia Basin demand for irrigation and various power demands at Metaline Falls.*

[Values in acre-feet.]

	2,000 second-feet for power.		3,000 second-feet for power.		4,000 second-feet for power.	
	Combined demand.	Draft from storage.	Combined demand.	Draft from storage.	Combined demand.	Draft from storage.
1919-20.						
April	679,600	.....	739,100	.....	798,600	.....
May	1,275,200	.....	1,336,700	.....	1,398,200	.....
June	1,271,200	.....	1,330,700	.....	1,390,200	.....
July	1,275,200	482,100	1,336,700	543,600	1,398,200	605,100
August	1,212,900	945,300	1,274,400	1,006,800	1,335,900	1,068,300
September	894,100	552,200	885,600	611,700	923,100	671,200
October	559,000	216,300	620,500	277,800	682,000	339,300
November	119,000	.....	178,500	.....	238,000	.....
December	123,000	.....	184,500	.....	246,000	.....
January	123,000	.....	184,500	.....	246,000	.....
February	115,000	.....	172,600	.....	230,100	.....
March	123,000	.....	184,500	.....	246,000	.....
Total	.....	2,195,900	.....	2,439,900	.....	2,683,900

TABLE 2A.—*Available run-offs at Newport and Metaline Falls and storage capacities required for different power demands*—Continued.

	5,000 second-feet for power.		6,000 second-feet for power.		7,000 second-feet for power.	
	Combined demand.	Draft from storage.	Combined demand.	Draft from storage.	Combined demand.	Draft from storage.
1919-20.						
April	858,100	.....	917,600	.....	977,100	.....
May	1,459,000	.....	1,521,100	.....	1,582,600	.....
June	1,449,700	.....	1,509,200	.....	1,568,700	.....
July	1,459,000	665,900	1,521,100	728,000	1,582,600	789,500
August	1,397,400	1,129,800	1,458,800	1,191,200	1,520,300	1,252,700
September	982,600	730,700	1,042,100	793,200	1,101,600	849,700
October	741,500	400,800	804,900	462,200	866,400	523,700
November	297,500	.....	357,000	.....	416,500	.....
December	307,500	.....	368,900	[1] 41,600	430,400	[2] 103,100
January	307,500	.....	368,900	.....	430,400	.....
February	287,600	.....	345,100	.....	402,600	.....
March	307,500	.....	368,900	.....	430,400	.....
Total	.....	2,927,200	.....	3,171,600	.....	3,508,300

[1] Stored during October and not held over irrigation period.
[2] Only 92,700 stored over irrigation period.

NOTE.—Storage capacity required increases by 244,000 acre-feet for each 1,000 second-feet increase in power demand up to 6,000 second-feet.

TABLE 3A.—*Showing monthly discharge of Flathead River at Polson, Mont., regulated by 1,560,000 acre-feet of storage in Flathead Lake operated in conjunction with 1,425,000 acre-feet of storage in Priest Lake and Pend Oreille Lake so as to satisfy full Columbia Basin demand and give quantities shown at Metaline Falls.*

[Storage in Pend Oreille Lake to elevation 2055, 1,265,000 acre-feet; in Priest Lake to elevation 2446, 160,000 acre-feet.]

	Available inflow to Flathead Lake.	Columbia Basin plus 2,000 second-feet at Metaline Falls.			Columbia Basin plus 3,000 second-feet at Metaline Falls.		
		Storage.	Regulated.	Discharge.	Storage.	Regulated.	Discharge.
1919-20.			*Acre-feet.*	*Second-feet.*		*Acre-feet.*	*Second-feet.*
April	793,300	.....	793,300	13,330	.....	793,300	13,330
May	2,275,100	+1,000,000	1,275,100	20,740	+1,000,000	1,275,100	20,740
June	1,518,500	+560,000	958,500	16,100	+560,000	958,500	16,100
July	355,600	−35,100	390,700	6,350	−96,500	452,100	7,350
August	178,100	−212,600	390,700	6,350	−274,100	452,200	7,350
September	71,100	−303,900	378,000	6,350	−366,500	437,600	7,350
October	85,400	−216,300	301,700	4,910	−277,800	363,200	5,900
November	139,100	−115,900	255,000	4,280	−67,700	206,800	3,470
December	85,700	−177,700	263,400	4,280	−128,000	213,700	3,470
January	102,900	−160,500	263,400	4,280	−110,700	213,600	3,470
February	87,000	−159,400	246,400	4,280	−112,900	199,900	3,470
March	87,800	−175,600	263,400	4,280	−125,800	213,600	3,470
Total	5,779,600	1,560,000	.....	.....	1,560,000	.....	.....

	Available inflow to Flathead Lake.	Columbia Basin plus 4,000 second-feet at Metaline Falls.			Columbia Basin plus 5,000 second-feet at Metaline Falls.		
		Storage.	Regulated.	Discharge.	Storage.	Regulated.	Discharge.
1919-20.			*Acre-feet.*	*Second-feet.*		*Acre-feet.*	*Second-feet.*
April	793,300	.....	793,300	13,330	.....	793,300	13,330
May	2,275,100	+1,000,000	1,275,100	20,740	+1,000,000	1,275,100	20,740
June	1,518,500	+560,000	958,500	16,100	+560,000	958,500	16,100
July	355,600	−158,100	513,700	8,350	−219,300	574,900	9,350
August	178,100	−335,500	513,600	8,350	−396,800	574,900	9,350
September	71,100	−426,000	497,100	8,350	−485,300	556,400	9,350
October	85,400	−339,500	424,700	6,910	−400,800	486,200	7,900
November	139,100	−19,500	158,600	2,660	+28,600	110,500	1,860
December	85,700	−78,200	163,900	2,660	−28,600	114,300	1,860
January	102,900	−61,000	163,900	2,660	−11,400	114,300	1,860
February	87,000	−66,300	153,300	2,660	−19,900	106,900	1,860
March	87,800	−76,100	163,900	2,660	−26,500	114,300	1,860
Total	5,779,600	.....	.....	.....	.....	.....	.....

TABLE 3B.—*Showing monthly discharge of Pend Oreille River at Metaline Falls as regulated by 560,000 acre-feet storage in Flathead Lake and 1,425,000 acre-feet of storage in Priest Lake and Pend Oreille Lake and after satisfying full Columbia Basin demand.*

[Storage in Pend Oreille Lake to elevation 2,066, 1,265,000 acre-feet; in Priest Lake to elevation 2,446 160,00 acre-feet.]

	Adjusted net flow at Metaline Falls.	Columbia Basin plus 2,000 second-feet at Metaline Falls.			Columbia Basin plus 3,000 second-feet at Metaline Falls.		
		Storage.	Regulated discharge.	For power.	Storage.	Regulated discharge.	For power.
1919–20.				*Second-feet.*			*Second-feet.*
April	2,083,400	.....	2,083,400	25,600	.....	2,083,400	25,600
May	4,298,300	+1,000,000	2,298,300	18,600	+1,000,000	2,298,300	18,600
June	3,545,100	+425,000	2,560,100	23,600	+425,000	2,560,100	23,600
July	793,100	−447,000	1,375,200	2,000	−447,100	1,336,700	3,000
August	267,600	−732,700	1,212,900	2,000	−732,700	1,274,400	3,000
September	251,900	−245,300	804,100	2,000	−245,300	863,600	3,000
October	342,700	.....	559,000	2,000	.....	620,500	3,000
November	426,900	.....	542,800	9,120	.....	404,600	8,310
December	327,300	.....	505,000	8,210	.....	455,300	7,400
January	463,300	.....	623,800	10,140	.....	574,000	9,330
February	449,600	.....	609,000	10,580	.....	562,500	9,790
March	554,300	.....	729,900	11,870	.....	680,100	11,100
Total	13,803,500	.....	13,803,500	.....	1,425,000	13,803,500	.....

	Adjusted net flow at Metaline Falls.	Columbia Basin plus 4,000 second-feet at Metaline Falls.			Columbia Basin plus 5,000 second-feet at Metaline Falls.		
		Storage.	Regulated discharge.	For power.	Storage.	Regulated discharge.	For power.
1919–20.				*Second-feet.*			*Second-feet.*
April	2,083,400	.....	2,083,400	25,600	.....	2,083,400	25,600
May	4,298,300	+1,000,000	2,298,300	18,600	+1,000,000	2,298,300	18,600
June	3,545,100	+425,000	2,560,100	23,600	+425,000	2,560,100	23,600
July	793,100	−447,000	1,398,200	4,000	−446,600	1,459,000	5,000
August	267,600	−732,800	1,335,900	4,000	−733,000	1,397,400	5,000
September	251,900	−245,200	923,100	4,000	−245,400	982,600	5,000
October	342,700	.....	682,000	4,000	.....	743,500	5,000
November	426,900	.....	446,400	7,500	.....	398,300	6,690
December	327,300	.....	405,500	6,580	.....	355,900	5,790
January	463,300	.....	524,300	8,530	.....	474,700	7,720
February	449,600	.....	515,900	8,970	.....	469,500	8,160
March	.....	.....	630,400	10,200	.....	580,800	9,450
Total	.....	.....	1,425,000	13,803,500	.....	13,803,500	.....

Total storage, 2,985,000 acre-feet.

TABLE 4A.—*Present irrigation demands for lands irrigated from the Columbia River and tributaries.*

River.	Area.	Demands in second-feet.							Total.
		April.	May.	June.	July.	August.	September.	October.	
	Acres.								*Acre-feet.*
Kettle	0								0
Colville	5,000	21	42	50	75	75	50	21	20,000
Spokane	10,000	42	84	100	150	150	100	42	40,000
Sanpoil	0								0
Okanogan	33,000	137	275	330	495	495	330	137	132,000
Methow	12,000	50	100	120	180	180	120	50	48,000
Chelan	3,000	13	26	30	44	44	30	13	12,000
Entiat	2,000	9	17	20	30	30	20	9	8,000
Wenatchee	25,000	105	208	250	375	375	250	105	100,000
Columbia	5,000	21	42	50	75	75	50	21	20,000
Total	95,000	398	794	950	1,364	1,424	1,010	398	380,000

TABLE 4B.—*Estimated future irrigation demands for lands susceptible of irrigation from the Columbia River and tributaries in Washington.*

	Area.	Demands in second-feet.							Total.
		April.	May.	June.	July.	August.	September.	October.	
	Acres.								*Acre-feet.*
Columbia Basin	1,750,000	9,420	18,740	19,360	18,740	17,730	11,510	7,090	6,225,200
Kettle River	5,625	25	50	60	90	90	60	25	22,500
Colville River	4,680	21	42	50	75	75	50	21	18,720
Spokane River	4,680	21	42	50	75	75	50	21	18,720
Sanpoil River	1,875	8	17	20	30	30	20	8	7,500
Okanogan River	16,875	75	150	180	270	270	180	75	67,500
Methow River	34,665	153	308	370	555	555	370	153	138,660
Chelan River	4,695	21	42	50	75	75	50	21	18,780
Entiat River	975	4	8	10	15	15	10	4	3,900
Wenatchee River	42,030	167	375	450	675	675	450	187	168,120
Columbia River	4,522	21	42	50	75	75	50	21	18,090
Total	1,870,622	9,936	19,816	20,650	20,675	19,665	12,800	7,626	6,710,690

TABLE 5.—*Estimated flow of Columbia River at mouth of important streams after satisfying anticipated future irrigation requirements on each stream.*

(Pend Oreille River assumed regulated by storage so as to provide minimum flow of 4,000 second-feet at Metaline Falls after satisfying Columbia Basin demand.)

[Values in second-feet.]

Season, 1919–20.	At mouth of Pend Oreille River.			At mouth of Kettle River.			
	Columbia River at trail.	Regulated discharge, Pend Oreille River.	Total flow.	Kettle River discharge.[1]	Total discharge.	Irrigation demand, Kettle River.	Remaining discharge.
April	31,400	25,600	60,000	7,010	67,010	25	66,985
May	107,000	18,600	125,600	12,000	137,600	50	137,550
June	195,000	23,600	218,600	8,360	226,960	60	226,900
July	179,000	4,000	183,000	2,150	185,150	90	185,060
August	119,000	4,000	123,000	512	123,512	90	123,422
September	72,500	4,000	76,500	458	76,958	60	76,898
October	34,700	4,000	38,700	987	39,687	25	39,662
November	21,800	7,500	29,300	1,420	30,720	.....	30,720
December	15,700	6,590	22,290	847	23,137	.....	23,137
January	15,200	8,530	23,730	800	24,530	.....	24,530
February	13,300	8,970	22,270	930	23,200	.....	23,200
March	11,700	10,200	21,900	878	22,778	.....	22,778
Total	819,300	125,590	944,890	36,352	981,242	.....	980,842

Season, 1919–20.	At mouth of Spokane River.				At mouth of Sanpoil River.			
	Spokane River discharge.	Total discharge.	Irrigation demand, Spokane River.	Remaining discharge.	Sanpoil River discharge.[2]	Total discharge.	Irrigation demand, Sanpoil River.	Remaining discharge.
April	22,443	89,427	63	89,364	863	90,227	8	90,219
May	21,084	158,634	126	158,508	811	159,319	17	159,302
June	9,260	236,160	150	236,010	435	236,445	20	236,425
July	3,210	188,270	225	188,045	176	188,221	30	188,191
August	2,800	126,222	225	125,997	66	126,063	30	126,033
September	2,670	79,568	150	79,418	48	79,466	20	79,446
October	2,542	42,204	63	42,141	55	42,196	8	42,188
November	2,620	33,340	.....	33,340	83	33,423	.....	33,423
December	2,700	25,837	.....	25,837	78	25,915	.....	25,915
January	2,680	27,210	.....	27,210	110	27,320	.....	27,320
February	3,410	26,610	.....	26,610	103	26,713	.....	26,713
March	6,630	29,408	.....	29,408	366	29,774	.....	29,774
Total	82,048	1,062,890	1,002	1,061,888	3,194	1,065,082	133	1,064,949

[1] Discharge records for 1914–15.

[2] Mean for seasons 1911–1918.

TABLE 5.—*Estimated flow of Columbia River at mouth of important streams after satisfying anticipated future irrigation requirements on each stream*—Continued.

Season 1919-20.	At mouth of Okanogan River.				At mouth of Methow River.			
	Okanogan River discharge.	Total discharge.	Irrigation demand.	Remaining discharge.	Methow River discharge.	Total discharge.	Irrigation demand.	Remaining discharge.
April	2,517	92,736	212	92,524	2,240	94,764	206	94,558
May	10,375	169,677	425	169,252	5,156	174,408	400	174,008
June	12,030	248,455	510	247,945	5,590	253,535	490	253,045
July	5,820	194,011	765	193,246	2,855	196,101	711	195,390
August	2,239	128,272	765	127,507	930	128,437	711	127,726
September	1,400	80,846	510	80,336	610	80,946	490	80,456
October	985	43,173	212	42,961	463	43,424	200	43,224
November	1,160	34,583	.....	34,583	443	35,026	.....	35,026
December	903	26,818	.....	26,818	336	27,154	.....	27,154
January	868	28,188	.....	28,188	370	28,558	.....	28,558
February	1,100	27,813	.....	27,813	366	28,179	.....	28,179
March	788	30,562	.....	30,562	361	30,923	.....	30,923
Total	40,185	1,105,134	3,399	1,101,735	19,720	1,121,455	3,208	1,118,247

Season 1919-20.	At mouth of Chelan River.				At mouth of Entiat River.			
	Chelan River discharge.	Total discharge.	Irrigation demand.	Remaining discharge.	Entiat River discharge.	Total discharge.	Irrigation demand.	Remaining discharge.
April	2,510	97,068	33	97,035	470	97,505	13	97,492
May	5,584	179,592	66	179,526	1,407	180,933	25	180,908
June	6,500	259,545	80	259,465	1,887	261,352	30	261,322
July	5,424	200,814	116	200,698	1,149	201,847	43	201,804
August	2,044	129,770	116	129,654	372	130,026	43	129,983
September	988	81,444	60	81,384	197	81,561	30	81,531
October	409	43,633	33	43,600	124	43,724	13	43,711
November	832	35,858	.....	35,858	131	35,989	.....	35,989
December	563	27,717	.....	27,717	114	27,831	.....	27,831
January	693	29,251	.....	29,251	127	29,378	.....	29,378
February	605	28,784	.....	28,784	124	28,908	.....	28,908
March	945	31,868	.....	31,868	121	31,989	.....	31,989
Total	27,097	1,145,344	524	1,144,820	6,223	1,151,043	197	1,150,846

Season 1919-20.	At mouth of Wenatchee River.				Other future demands above Priest Rapids.	
	Wenatchee River discharge.[3]	Total discharge.	Irrigation demand.	Remaining discharge.	Future demand.	Remaining discharge.
April	5,000	102,492	287	102,205	21	102,184
May	9,107	190,015	564	189,451	42	189,409
June	9,803	271,125	700	270,425	50	270,375
July	7,663	209,467	1,015	208,452	75	208,377
August	2,766	132,749	1,015	131,734	75	131,659
September	1,186	82,717	700	82,017	50	81,967
October	690	44,401	277	44,124	21	44,103
November	1,920	37,909	.....	37,909	.....	37,909
December	1,590	29,411	.....	29,411	.....	29,411
January	2,320	31,698	.....	31,698	.....	31,698
February	1,850	30,758	.....	30,758	.....	30,758
March	1,700	33,689	.....	33,689	.....	33,689
Total	45,585	1,196,431	4,558	1,191,873	.....	.....

[3] Discharge estimated by comparison between previous records at Dryden and mouth of Beaver Creek near Leavenworth.

TABLE 5.—*Estimated flow of Columbia River at mouth of important streams after satisfying anticipated future irrigation requirements on each stream*—Continued.

Season 1919-20.	Columbia River at Vernita.				
	Observed discharge.	Correction for storage above.[4]	Regulated discharge.	Total all future demands for irrigation.	Remaining estimated discharge.
April	96,600	+11,320	107,920	9,936	97,984
May	221,000	−13,660	207,340	19,816	187,524
June	335,000	−24,740	330,360	20,650	309,710
July	261,000	−8,960	252,040	20,675	231,365
August	154,000	+8,120	162,120	19,665	142,455
September	92,200	+7,170	99,370	12,800	86,570
October	49,700	+4,330	54,030	7,626	46,404
November	36,400	+410	36,810	.....	36,810
December	28,100	+1,120	29,220	.....	29,220
January	27,500	+1,730	29,230	.....	29,230
February	31,100	+330	31,430	.....	31,430
March	32,100	+2,000	34,100	.....	34,100

[4] Includes also irrigation demand in Montana.

LIST OF DIAGRAMS.

Hydrographs of Columbia Basin demand.

Hydrograph of Columbia River at mouth of San Poil River.

Hydrograph of Columbia River at Kettle Falls.

Hydrograph of Columbia River at Vernita.

Monthly hydrograph of Pend Oreille River at Metaline Falls for minimum year April, 1919, to March, 1920, showing gauged flow and flow corrected for influence upon monthly stream discharge by reason of natural storage in Pend Oreille and Flathead Lakes.

Hydrograph of Flathead and Pend Oreille Rivers showing parallel operation of storage on Flathead, Pend Oreille, and Priest Lakes to satisfy Columbia Basin demand and give 2,000 second-feet minimum at Metaline Falls, minimum year April, 1919, to March, 1920. Storage of 1,560,000 acre-feet in Flathead Lake, 1,265,000 acre-feet in Pend Oreille Lake, and 160,000 acre-feet in Priest Lake.

Same hydrograph as above giving 3,000 second-feet minimum at Metaline Falls.

Same hydrograph as above giving 4,000 second-feet minimum at Metaline Falls.

Same hydrograph as above giving 5,000 second-feet minimum at Metaline Falls.

Diagram showing relation between discharge available for power development in Flathead River and at Metaline Falls after future irrigation demands in Montana and demand of full Columbia Basin project, based on minimum discharge season April, 1919, to March, 1920.

Developed water power in upper Columbia River drainage basin in Washington.

[From U. S. Geological Survey.]

Ownership.	Town and county.	Stream.	Location of power plant.	Rated capacity.		Head.
				Water wheels.	Generators.	
				Horsepower.	*Kv.A.*	*Feet.*
Black Rock Power & Irrigation Co.	Priest Rapids, Yakima County.	Columbia River.	Sec. 2, T. 13 N., R. 33 E.	2,000	[1] 1,800	26
Lehigh Portland Cement Co.	Metaline Falls, Pend Oreille County.	Sullivan Creek	Sec. 22, T. 39 N., R. 43 E.	6,000	3,530	460
Kulzer Electric System.	Stevens County...	Jumpoff Creek	Sec. 26, T. 31 N., R. 40 E.	300	85	310
Republic Light & Power Co.	Republic, Ferry County.	O'Brien Creek	T. 36 N., R. 33 E.....	150	75	188
Stevens County Power & Light Co.	Meyers Falls, Stevens County.	Colville River.	Sec. 29, T. 36 N., R. 38 E.	1,600	1,200	133
Spokane municipal water supply.	Spokane, Spokane County.	Spokane River	Sec. 11, T. 25 N., R. 43 E.	3,800	Pumps.	16–24
Washington Water Power Co.	Spokane, upper falls.	.....do.....	Sec. 18, T. 25 N., R. 43 E.	14,250	[1] 11,750	65
Do.....	Spokane, lower falls.	.....do.....	Sec. 18, T. 25 N., R. 43 E.	15,800	9,500	64–74
Spokane & Eastern Railway & Power Co.	Ninemile Falls, Spokane County.	.....do.....	Sec. 6, T. 26 N., R. 42 E.	22,000	12,000	58
Washington Water Power Co.	Long Lake, Lincoln County.	Spokane River	Sec. 13, T. 27 N., R. 39 E.	67,500	[1] 52,500	172
Do.....	Little Falls, Stevens County.	.....do.....	Sec. 20, T. 27 N., R. 39 E.	36,000	[1] 29,500	73
Mount Spokane Power Co.	Milan, Spokane County.	Little Spokane River.	Sec. 2, T. 28 N., R. 43 E.	400	200	24
United States Reclamation Service.	Okanogan, Okanogan County.	Salmon Creek, drop in upper main lateral.	Sec. 29, T. 34 N., R. 26 E.	250	187	58
Do.....	.....do.....	Drop in mainland.	Sec. 5, T. 33 N., R. 26 E.	250	187	108
Okanogan Valley Power Co.	Oroville, Okanogan County.	Similkameen River.	Sec. 13, T. 40 N., R. 26 E.	2,500	2,000	79
Do.....	Pateros, Okanogan County.	Methow River.	Sec. 34, T. 30 N., R. 23 E.	700	450	26
Twisp Light & Power Co.	Twisp, Okanogan County.	Twisp River..	Sec. 12, T. 33 N., R. 21 E.	171	50	23–26
Twisp Roller Mills & Power Co.	.....do.....	.....do.....	Sec. 8, T. 33 N., R. 22 E.	172	[2] 6	21
Chelan Electric Co.	Chelan, Chelan County.	Chelan River..	Sec. 18, T. 27 N., R. 23 E.	270	125	11–15
Chelan Falls Power Co.	.....do.....	.....do.....	Sec. 29, T. 27 N., R. 23 E.	1,100	1,000	30–35
Washington Coast Utilities Co.	Entiat, Chelan County.	Entiat River..	Sec. 18, T. 25 N., R. 21 E.	2,000	1,375	78
Great Northern Ry. Co.	Leavenworth, Chelan County.	Wenatchee River.	Sec. 10, T. 24 N., R. 17 E.	12,000	7,500	200
Tumwater Light & Power Co.	.....do.....	.....do.....	Sec. 10, T. 24 N., R. 17 E.	250	200	59–62
Washington Coast Utilities Co.	Dryden, Chelan County.	.....do.....	Sec. 26, T. 24 N., R. 18 E.	2,380	1,750	55
City of Ellenburg.	Ellenburg, Kittitas County.	Yakima River	Sec. 32, T. 18 N., R. 18 E.	1,600	1,090	52
Pacific Power & Light Co.	Naches, Yakima County.	Naches River.	Sec. 3, T. 14 N., R. 17 E.	1,900	1,750	53
Do.....	.....do.....	.....do.....	Sec. 13, T. 14 N., R. 17 E.	10,100	8,440	151
Do.....	Yakima, Yakima County.	.....do.....	Sec. 23, T. 13 N., R. 18 E.	500	425	38
United States Reclamation Service.	Rimrock, Yakima County.	Tieton River..	Sec. 31, T. 14 N., R. 14 E.	1,400	1,000	75
Do.....	(Snipes Mountain Plant), Yakima County.	Yakima River, Sunnyside Canal.	Sec. 2, T. 9 N., R. 22 E.	500	([3])	63
Do.....	(Rocky Ford plant), Yakima County.	.....do.....	Sec. 27, T. 9 N., R. 23 E.	200	187	73

[1] Kilowatt. [2] Flour mill. [3] Pumping.

Developed water power in upper Columbia River drainage basin in Washington—Con.

Ownership.	Town and county.	Stream.	Location of power plant.	Rated capacity.		Head.
				Water wheels.	Generators.	
				Horsepower.	*Kv.A.*	*Feet.*
United States Reclamation Service.	(Grandview plant), Benton County.	Yakima River, Sunnyside Canal.	Sec. 30, T. 9 N., R. 24 E.	200	([3])	21
Do.....	(Prosser plant), Benton County.	.....do.....	Sec. 26, T. 9 N., R. 24 E.	200	([3])	52
Do.....	(Spring Creek plant), Benton County.	.....do.....	Sec. 20, T. 9 N., R. 25 E.	200	([3])	77
Do.....	(Outlook plant), Yakima County.	.....do.....	Sec. 9, T. 10 N., R. 22 E.	800	([3])	46
Total.....				209,400	140,800	.....

[3] Pumping.

Developed water power in upper Columbia River drainage basin, British Columbia.

Ownership.	Nearest town.	Stream.	Location of power plant.	Rated capacity.		Head.
				Water wheels.	Generators.	
				Horsepower.	*K.V.A.*	*Feet.*
City of Revelstoke.....	Revelstoke...	Illecillewaet River	1½ miles above mouth. ...	2,300	1,200	72
Hedley Gold Mining Co.	Hedley.....	Hedley Creek.....	Near mouth.....	400	360	400
Do.....	.....do.....	Similkameen River.	3 miles below Hedley Creek.	2,100	1,250	62
City of Nelson.....	Nelson.....	Kootenai River...	Upper Bonnington Falls.	3,400	1,750	60
West Kootenai Power & Light Co.	.....do.....	.....do.....	Lower Bonnington Falls.	4,000	3,000	34
Do.....	.....do.....	.....do.....	Upper Bonnington Falls.	34,000	26,250	67
Do.....	Cascade.....	Kettle River.....	12 miles below Grand Forks.	3,900	2,250	156
Granby Mining, Smelting & Power Co.	Grand Forks.	North Fork Kettle River.	.....	860	540	30
Greenwood City Water Works.	Greenwood...	Boundary Creek...	Boundary Falls..	165	125	60
British Canadian Alberta Power Co. (Ltd.).	Bull River Falls.	Bull River.....	.....	6,000	4,000	275
City of Kaslo.....	Kaslo.....	Kaslo.....	1½ miles from mouth.	250	120	41
New Denver Power & Light Co.	New Denver.	Carpenter Creek...	2 miles below lake.	55	93	84
Total.....				57,430	40,940	.....

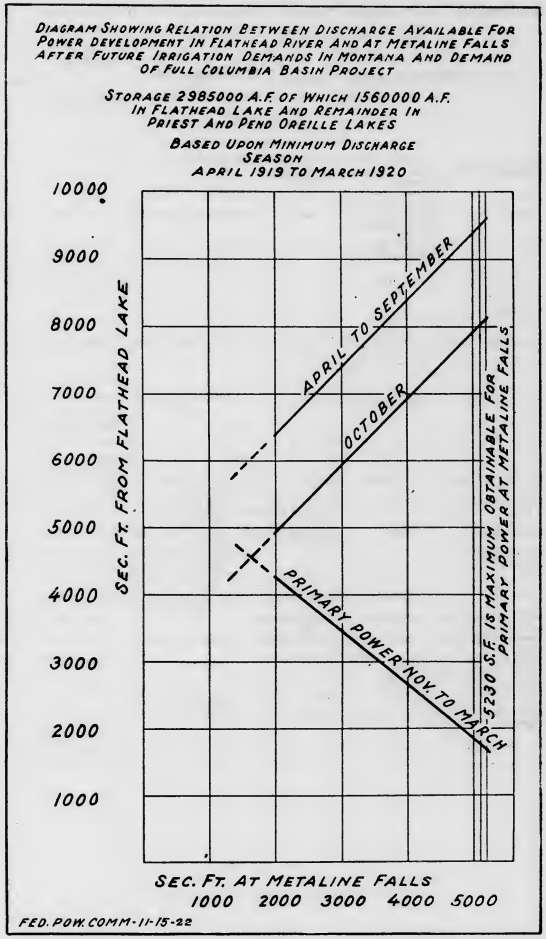
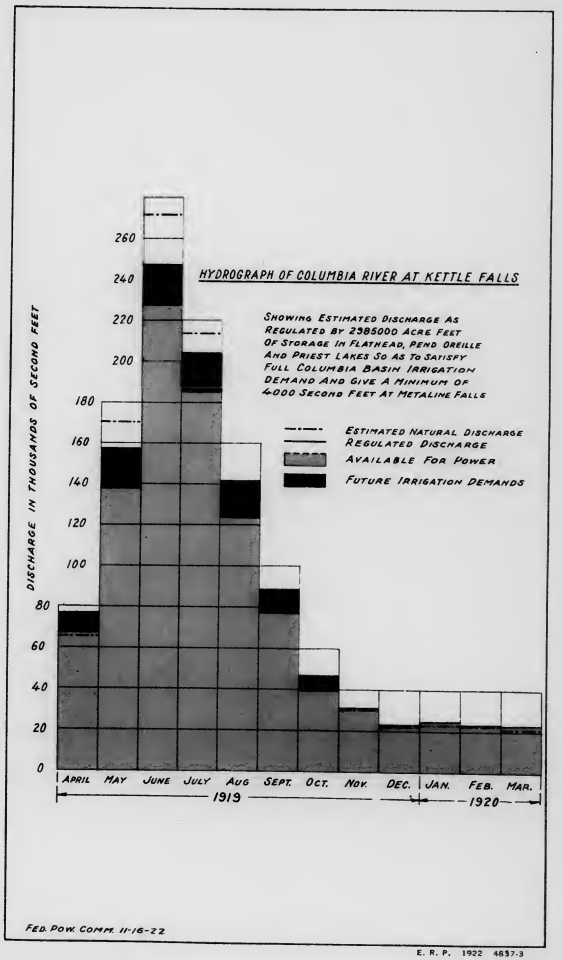


DIAGRAM SHOWING RELATION BETWEEN DISCHARGE AVAILABLE FOR POWER DEVELOPMENT IN FLATHEAD RIVER AND AT METALINE FALLS AFTER FUTURE IRRIGATION DEMANDS IN MONTANA AND DEMAND OF FULL COLUMBIA BASIN PROJECT
STORAGE 2985000 A.F. OF WHICH 1560000 A.F. IN FLATHEAD LAKE AND REMAINDER IN PRIEST AND PEND OREILLE LAKES
BASED UPON MINIMUM DISCHARGE SEASON APRIL 1919 TO MARCH 1920
SEC. FT. FROM FLATHEAD LAKE
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
APRIL TO SEPTEMBER
OCTOBER
PRIMARY POWER NOV. TO MARCH
3230 S.F. IS MAXIMUM OBTAINABLE FOR PRIMARY POWER AT METALINE FALLS
SEC. FT. AT METALINE FALLS
1000 2000 3000 4000 5000
FED. POW. COMM. 11-15-22



E. R. P. 1922 4857-3

INTENTIONAL SECOND EXPOSURE

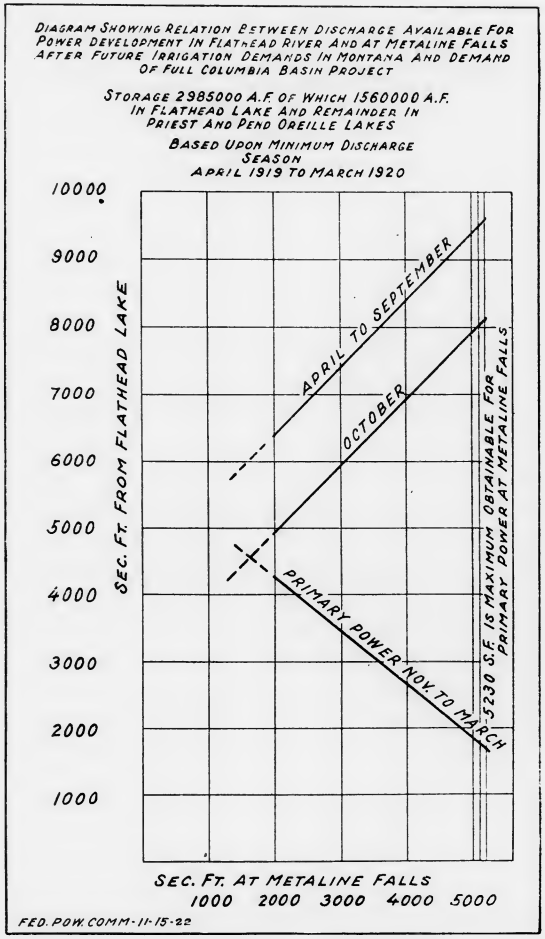
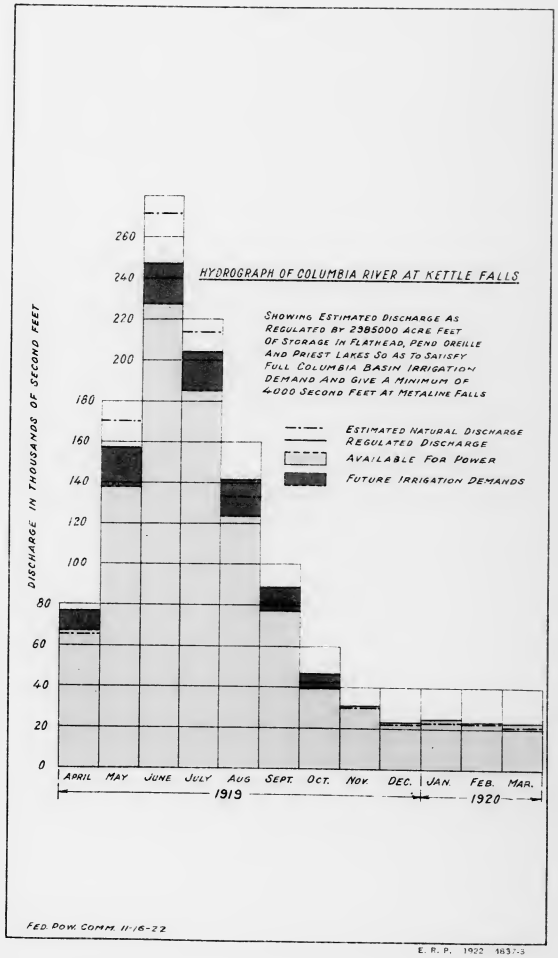
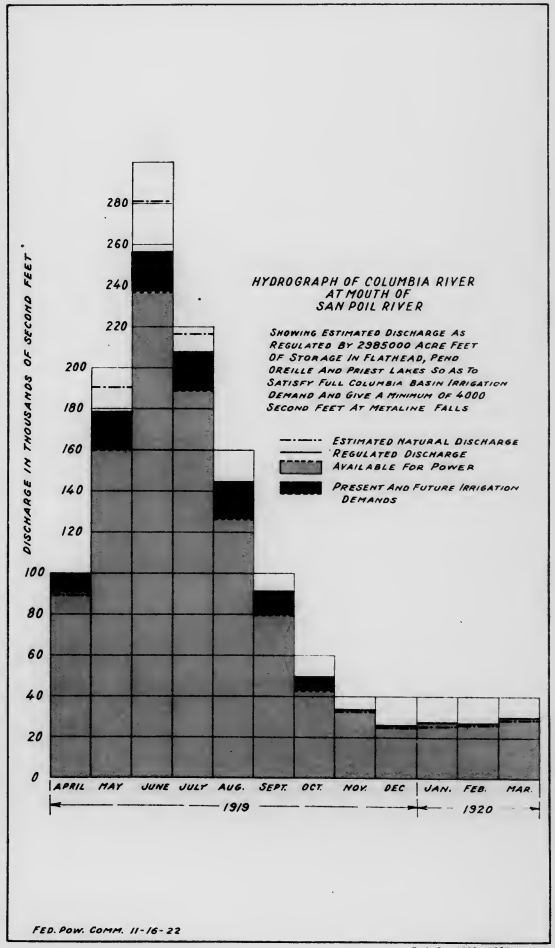


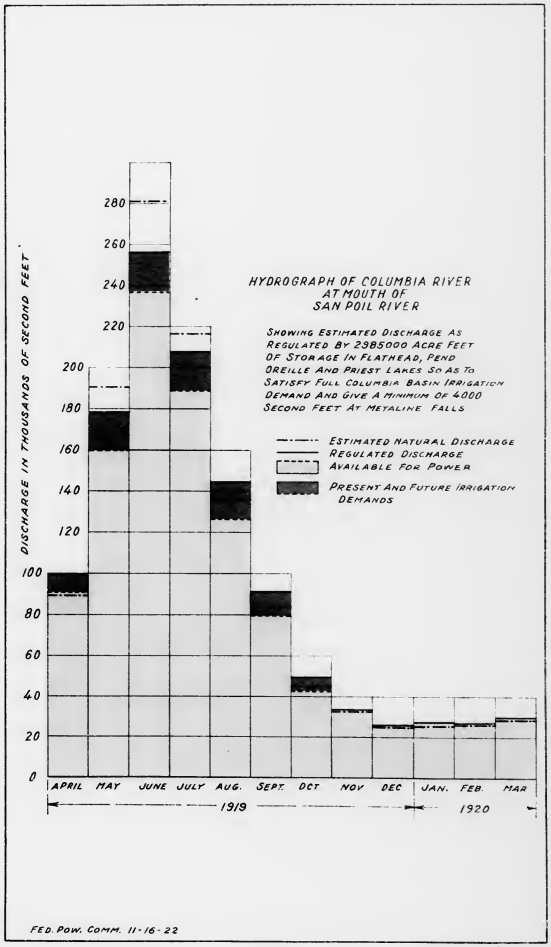
DIAGRAM SHOWING RELATION BETWEEN DISCHARGE AVAILABLE FOR POWER DEVELOPMENT IN FLATHEAD RIVER AND AT METALINE FALLS AFTER FUTURE IRRIGATION DEMANDS IN MONTANA AND DEMAND OF FULL COLUMBIA BASIN PROJECT
STORAGE 2985000 A.F. OF WHICH 1560000 A.F. IN FLATHEAD LAKE AND REMAINDER IN PRIEST AND PEND OREILLE LAKES
BASED UPON MINIMUM DISCHARGE SEASON APRIL 1919 TO MARCH 1920
SEC. FT. FROM FLATHEAD LAKE
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
APRIL TO SEPTEMBER
OCTOBER
PRIMARY POWER NOV. TO MARCH
3230 S.F. IS MAXIMUM OBTAINABLE FOR PRIMARY POWER AT METALINE FALLS
SEC. FT. AT METALINE FALLS
1000 2000 3000 4000 5000
FED. POW. COMM. 11-15-22

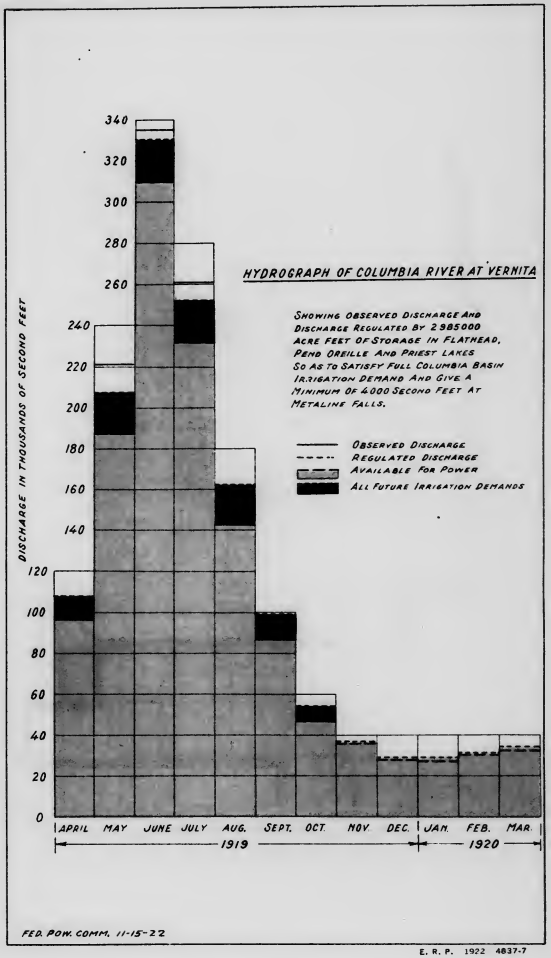


E. P. P. 1922 1857-3

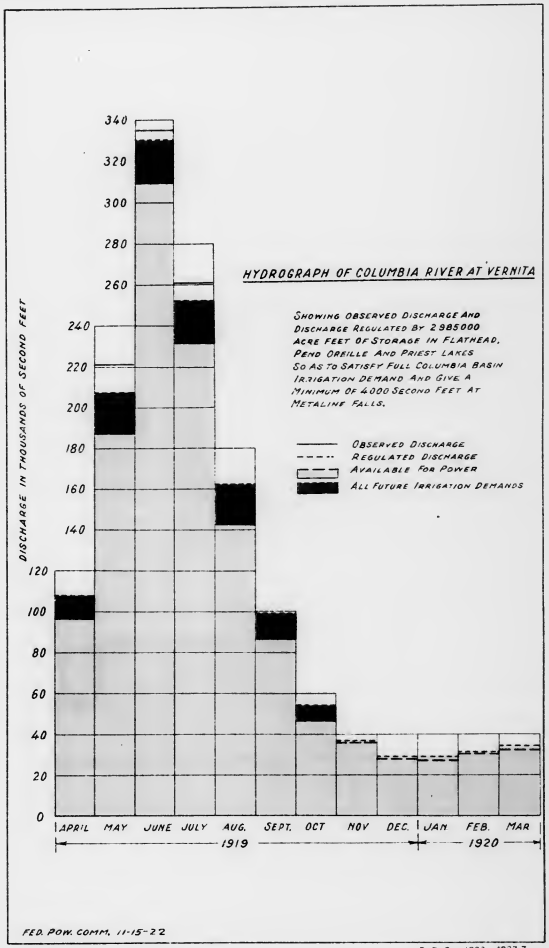

HYDROGRAPH OF COLUMBIA RIVER
AT MOUTH OF
SAN POIL RIVER
SHOWING ESTIMATED DISCHARGE AS REGULATED BY 2985000 ACRE FEET OF STORAGE IN FLATHEAD, PEND OREILLE AND PRIEST LAKES SO AS TO SATISFY FULL COLUMBIA BASIN IRRIGATION DEMAND AND GIVE A MINIMUM OF 4000 SECOND FEET AT METALINE FALLS
ESTIMATED NATURAL DISCHARGE
REGULATED DISCHARGE
AVAILABLE FOR POWER
PRESENT AND FUTURE IRRIGATION DEMANDS
DISCHARGE IN THOUSANDS OF SECOND FEET.
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC
JAN.
FEB.
MAR.
1919
1920
FED. POW. COMM. 11-16-22
E. R. P. 1922 4837-4

INTENTIONAL SECOND EXPOSURE

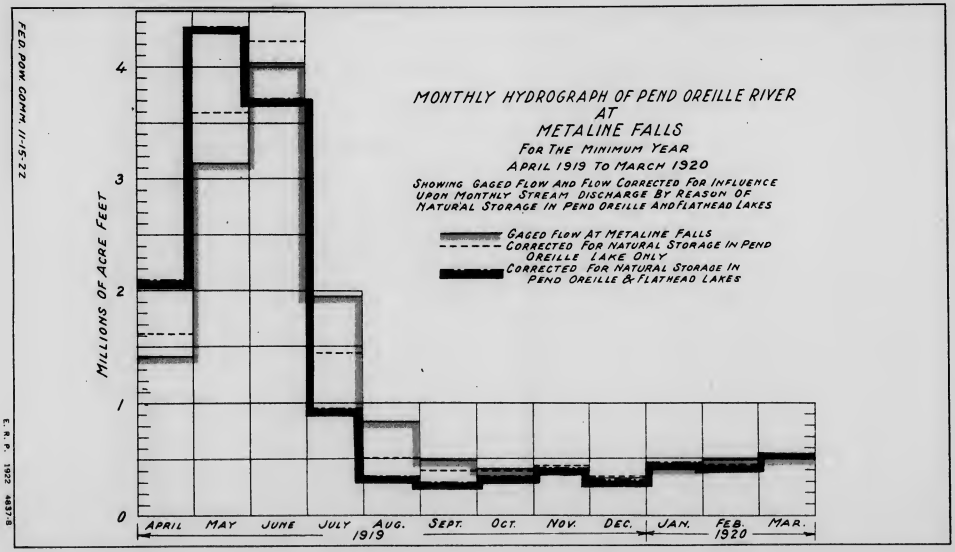



HYDROGRAPH OF COLUMBIA RIVER AT VERNITA
SHOWING OBSERVED DISCHARGE AND DISCHARGE REGULATED BY 2985000 ACRE FEET OF STORAGE IN FLATHEAD, POND OREILLE AND PRIEST LAKES SO AS TO SATISFY FULL COLUMBIA BASIN IRRIGATION DEMAND AND GIVE A MINIMUM OF 4000 SECOND FEET AT METALINE FALLS.
OBSERVED DISCHARGE
REGULATED DISCHARGE
AVAILABLE FOR POWER
ALL FUTURE IRRIGATION DEMANDS
DISCHARGE IN THOUSANDS OF SECOND FEET
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MAR.
1919
1920
FED. POW. COMM. 11-15-22
E. R. P. 1922 4837-7

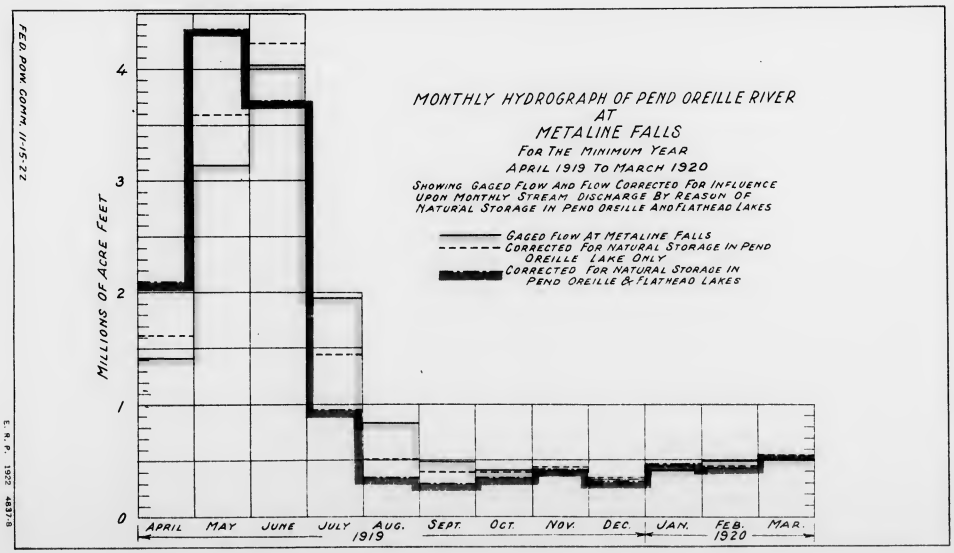
INTENTIONAL SECOND EXPOSURE



E. R. P. 1922 4837-7


FED POW COMM 11-15-22
MONTHLY HYDROGRAPH OF PEND OREILLE RIVER
AT
METALINE FALLS
FOR THE MINIMUM YEAR
APRIL 1919 TO MARCH 1920
SHOWING GAGED FLOW AND FLOW CORRECTED FOR INFLUENCE UPON MONTHLY STREAM DISCHARGE BY REASON OF NATURAL STORAGE IN PEND OREILLE AND FLATHEAD LAKES
GAGED FLOW AT METALINE FALLS
CORRECTED FOR NATURAL STORAGE IN PEND OREILLE LAKE ONLY
CORRECTED FOR NATURAL STORAGE IN PEND OREILLE & FLATHEAD LAKES
MILLIONS OF ACRE FEET
0
1
2
3
4
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MAR.
1919
1920
E. R. P. 1922 4837-9

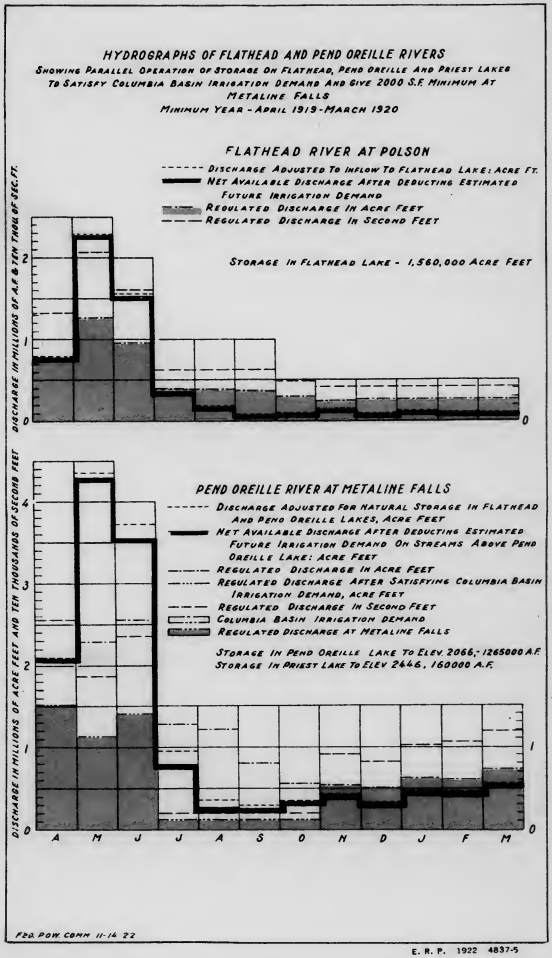
INTENTIONAL SECOND EXPOSURE



HYDROGRAPHS OF FLATHEAD AND PEND OREILLE RIVERS

Showing Parallel Operation of Storage On Flathead, Pend Oreille and Priest Lakes To Satisfy Columbia Basin Irrigation Demand And Give 2000 S.F. Minimum At Metaline Falls

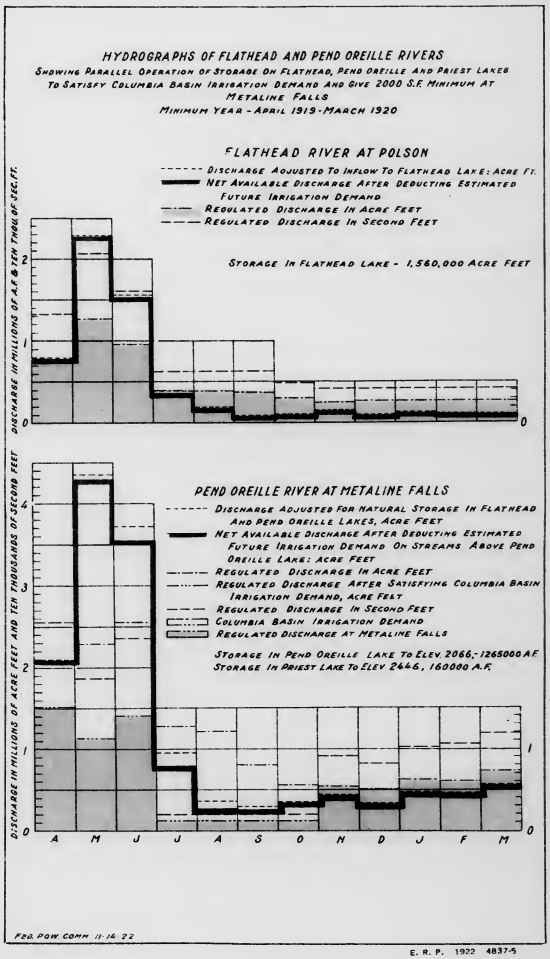
Minimum Year - April 1919-March 1920


FLATHEAD RIVER AT POLSON
Discharge Adjusted To Inflow To Flathead Lake: Acre Ft.
Net Available Discharge After Deducting Estimated Future Irrigation Demand
Regulated Discharge In Acre Feet
Regulated Discharge In Second Feet
Storage In Flathead Lake - 1,560,000 Acre Feet
DISCHARGE IN MILLIONS OF A.F. & TEN THOUSANDS OF SEC. FT.
2
0
PEND OREILLE RIVER AT METALINE FALLS
Discharge Adjusted For Natural Storage In Flathead And Pend Oreille Lakes, Acre Feet
Net Available Discharge After Deducting Estimated Future Irrigation Demand On Streams Above Pend Oreille Lake: Acre Feet
Regulated Discharge In Acre Feet
Regulated Discharge After Satisfying Columbia Basin Irrigation Demand, Acre Feet
Regulated Discharge In Second Feet
Columbia Basin Irrigation Demand
Regulated Discharge At Metaline Falls
Storage In Pend Oreille Lake To Elev 2065,- 1265000 A.F.
Storage In Priest Lake To Elev 2646, 160000 A.F.
DISCHARGE IN MILLIONS OF ACRE FEET AND TEN THOUSANDS OF SECOND FEET
2
1
0
A M J J A S O N D J F M

Fed. Pow. Comm 11-14-22

E. R. P. 1922 4837-5

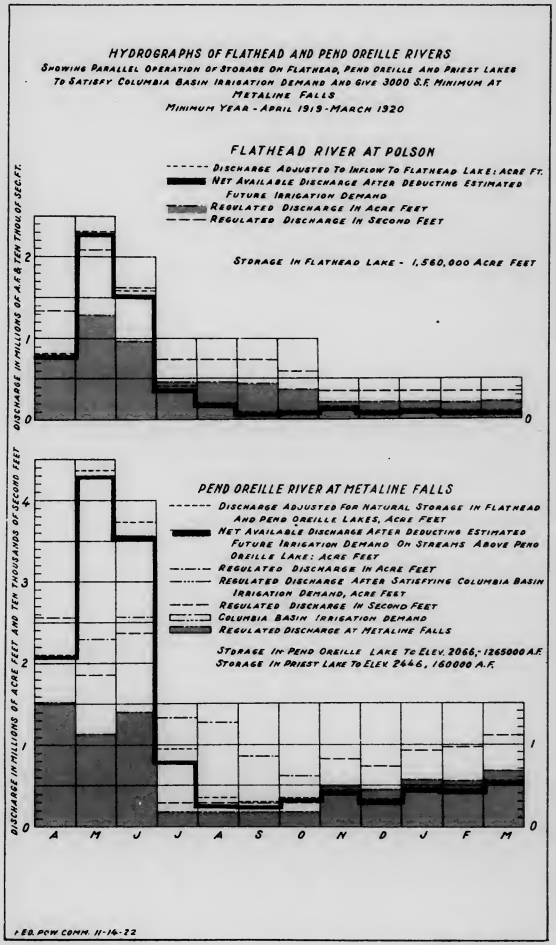
INTENTIONAL SECOND EXPOSURE


HYDROGRAPHS OF FLATHEAD AND PEND OREILLE RIVERS
SHOWING PARALLEL OPERATION OF STORAGE ON FLATHEAD, PEND OREILLE AND PRIEST LAKES TO SATISFY COLUMBIA BASIN IRRIGATION DEMAND AND GIVE 2000 S.F. MINIMUM AT METALINE FALLS
MINIMUM YEAR - APRIL 1919 - MARCH 1920
FLATHEAD RIVER AT POLSON
DISCHARGE ADJUSTED TO INFLOW TO FLATHEAD LAKE: ACRE FT.
NET AVAILABLE DISCHARGE AFTER DEDUCTING ESTIMATED FUTURE IRRIGATION DEMAND
REGULATED DISCHARGE IN ACRE FEET
REGULATED DISCHARGE IN SECOND FEET
STORAGE IN FLATHEAD LAKE - 1,560,000 ACRE FEET
DISCHARGE IN MILLIONS OF A.F. & TEN THOUSANDS OF SEC. FT.
PEND OREILLE RIVER AT METALINE FALLS
DISCHARGE ADJUSTED FOR NATURAL STORAGE IN FLATHEAD AND PEND OREILLE LAKES, ACRE FEET
NET AVAILABLE DISCHARGE AFTER DEDUCTING ESTIMATED FUTURE IRRIGATION DEMAND ON STREAMS ABOVE PEND OREILLE LAKE: ACRE FEET
REGULATED DISCHARGE IN ACRE FEET
REGULATED DISCHARGE AFTER SATISFYING COLUMBIA BASIN IRRIGATION DEMAND, ACRE FEET
REGULATED DISCHARGE IN SECOND FEET
COLUMBIA BASIN IRRIGATION DEMAND
REGULATED DISCHARGE AT METALINE FALLS
STORAGE IN PEND OREILLE LAKE TO ELEV 2066,- 1265000 A.F.
STORAGE IN PRIEST LAKE TO ELEV 2446, 160000 A.F.
DISCHARGE IN MILLIONS OF ACRE FEET AND TEN THOUSANDS OF SECOND FEET
A M J J A S O N D J F M
FED. POW. COMM. 11-14-22
E. R. P. 1922 4837-5

HYDROGRAPHS OF FLATHEAD AND PEND OREILLE RIVERS

SHOWING PARALLEL OPERATION OF STORAGE ON FLATHEAD, PEND OREILLE AND PRIEST LAKES TO SATISFY COLUMBIA BASIN IRRIGATION DEMAND AND GIVE 3000 S.F. MINIMUM AT METALINE FALLS

MINIMUM YEAR - APRIL 1919 - MARCH 1920


FLATHEAD RIVER AT POLSON
DISCHARGE ADJUSTED TO INFLOW TO FLATHEAD LAKE: ACRE FT.
NET AVAILABLE DISCHARGE AFTER DEDUCTING ESTIMATED FUTURE IRRIGATION DEMAND
REGULATED DISCHARGE IN ACRE FEET
REGULATED DISCHARGE IN SECOND FEET
STORAGE IN FLATHEAD LAKE - 1,560,000 ACRE FEET
DISCHARGE IN MILLIONS OF A.F. & TEN THOU. OF SEC. FT.
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PEND OREILLE RIVER AT METALINE FALLS
DISCHARGE ADJUSTED FOR NATURAL STORAGE IN FLATHEAD AND PEND OREILLE LAKES, ACRE FEET
NET AVAILABLE DISCHARGE AFTER DEDUCTING ESTIMATED FUTURE IRRIGATION DEMAND ON STREAMS ABOVE PEND OREILLE LAKE: ACRE FEET
REGULATED DISCHARGE IN ACRE FEET
REGULATED DISCHARGE AFTER SATISFYING COLUMBIA BASIN IRRIGATION DEMAND, ACRE FEET
REGULATED DISCHARGE IN SECOND FEET
COLUMBIA BASIN IRRIGATION DEMAND
REGULATED DISCHARGE AT METALINE FALLS
STORAGE IN PEND OREILLE LAKE TO ELEV. 2066, - 1265000 A.F.
STORAGE IN PRIEST LAKE TO ELEV. 2646, 160000 A.F.
DISCHARGE IN MILLIONS OF ACRE FEET AND TEN THOUSANDS OF SECOND FEET
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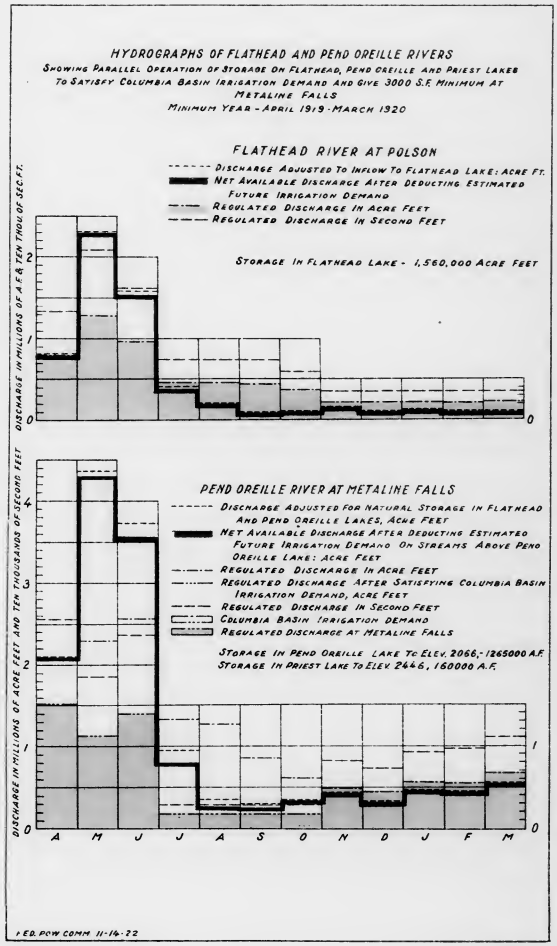
FED. POW COMM. 11-14-22

E. R. P. 1922 4837-1

INTENTIONAL SECOND EXPOSURE


HYDROGRAPHS OF FLATHEAD AND PEND OREILLE RIVERS
SHOWING PARALLEL OPERATION OF STORAGE ON FLATHEAD, PEND OREILLE AND PRIEST LAKES TO SATISFY COLUMBIA BASIN IRRIGATION DEMAND AND GIVE 3000 S.F. MINIMUM AT METALINE FALLS
MINIMUM YEAR - APRIL 1919 - MARCH 1920
FLATHEAD RIVER AT POLSON
DISCHARGE ADJUSTED TO INFLOW TO FLATHEAD LAKE: ACRE FT.
NET AVAILABLE DISCHARGE AFTER DEDUCTING ESTIMATED FUTURE IRRIGATION DEMAND
REGULATED DISCHARGE IN ACRE FEET
REGULATED DISCHARGE IN SECOND FEET
STORAGE IN FLATHEAD LAKE - 1,560,000 ACRE FEET
DISCHARGE IN MILLIONS OF A.F. & TEN THOUS. OF SEC. FT.
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PEND OREILLE RIVER AT METALINE FALLS
DISCHARGE ADJUSTED FOR NATURAL STORAGE IN FLATHEAD AND PEND OREILLE LAKES, ACRE FEET
NET AVAILABLE DISCHARGE AFTER DEDUCTING ESTIMATED FUTURE IRRIGATION DEMAND ON STREAMS ABOVE PEND OREILLE LAKE: ACRE FEET
REGULATED DISCHARGE IN ACRE FEET
REGULATED DISCHARGE AFTER SATISFYING COLUMBIA BASIN IRRIGATION DEMAND, ACRE FEET
REGULATED DISCHARGE IN SECOND FEET
COLUMBIA BASIN IRRIGATION DEMAND
REGULATED DISCHARGE AT METALINE FALLS
STORAGE IN PEND OREILLE LAKE TO ELEV. 2056; 1265000 A.F.
STORAGE IN PRIEST LAKE TO ELEV 2446, 160000 A.F.
DISCHARGE IN MILLIONS OF ACRE FEET AND TEN THOUSANDS OF SECOND FEET
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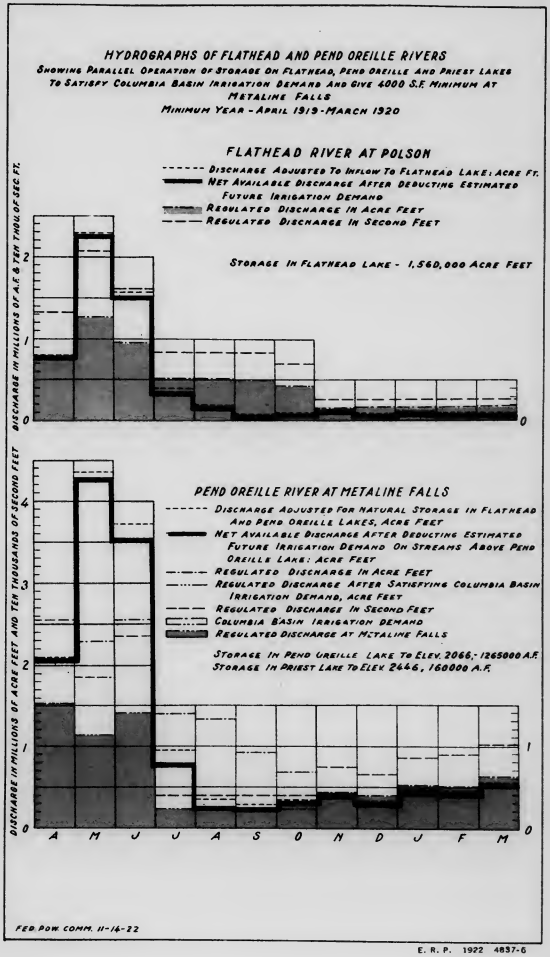
E. R. P. 1922 4837-1

HYDROGRAPHS OF FLATHEAD AND PEND OREILLE RIVERS

SHOWING PARALLEL OPERATION OF STORAGE ON FLATHEAD, PEND OREILLE AND PRIEST LAKES TO SATISFY COLUMBIA BASIN IRRIGATION DEMAND AND GIVE 4000 S.F. MINIMUM AT METALINE FALLS

MINIMUM YEAR - APRIL 1919 - MARCH 1920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DISCHARGE ADJUSTED TO INFLOW TO FLATHEAD LAKE: ACRE FT.
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REGULATED DISCHARGE IN ACRE FEET
REGULATED DISCHARGE IN SECOND FEET
STORAGE IN FLATHEAD LAKE - 1,560,000 ACRE FEET
DISCHARGE IN MILLIONS OF A.F. & TEN THOUSANDS OF SEC. FT.
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PEND OREILLE RIVER AT METALINE FALLS
DISCHARGE ADJUSTED FOR NATURAL STORAGE IN FLATHEAD AND PEND OREILLE LAKES, ACRE FEET
NET AVAILABLE DISCHARGE AFTER DEDUCTING ESTIMATED FUTURE IRRIGATION DEMAND ON STREAMS ABOVE PEND OREILLE LAKE: ACRE FEET
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REGULATED DISCHARGE IN SECOND FEET
COLUMBIA BASIN IRRIGATION DEMAND
REGULATED DISCHARGE AT METALINE FALLS
STORAGE IN PEND OREILLE LAKE TO ELEV. 2066; - 1265000 A.F.
STORAGE IN PRIEST LAKE TO ELEV. 2446, 160000 A.F.
DISCHARGE IN MILLIONS OF ACRE FEET AND TEN THOUSANDS OF SECOND FEET
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A M J J A S O N D J F M

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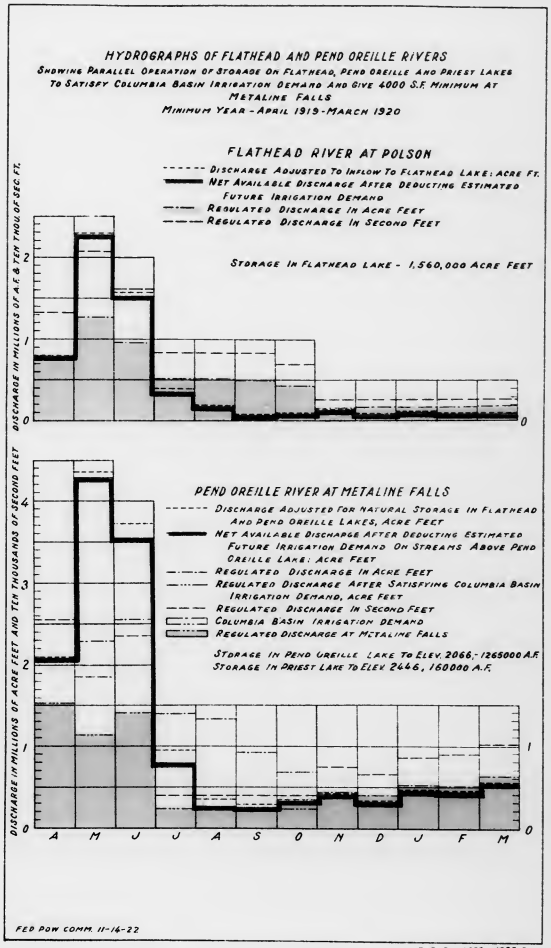
INTENTIONAL SECOND EXPOSURE


HYDROGRAPHS OF FLATHEAD AND PEND OREILLE RIVERS
SHOWING PARALLEL OPERATION OF STORAGE ON FLATHEAD, PEND OREILLE AND PRIEST LAKES TO SATISFY COLUMBIA BASIN IRRIGATION DEMAND AND GIVE 4000 S.F. MINIMUM AT METALINE FALLS
MINIMUM YEAR - APRIL 1919 - MARCH 1920
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DISCHARGE ADJUSTED TO INFLOW TO FLATHEAD LAKE: ACRE FT.
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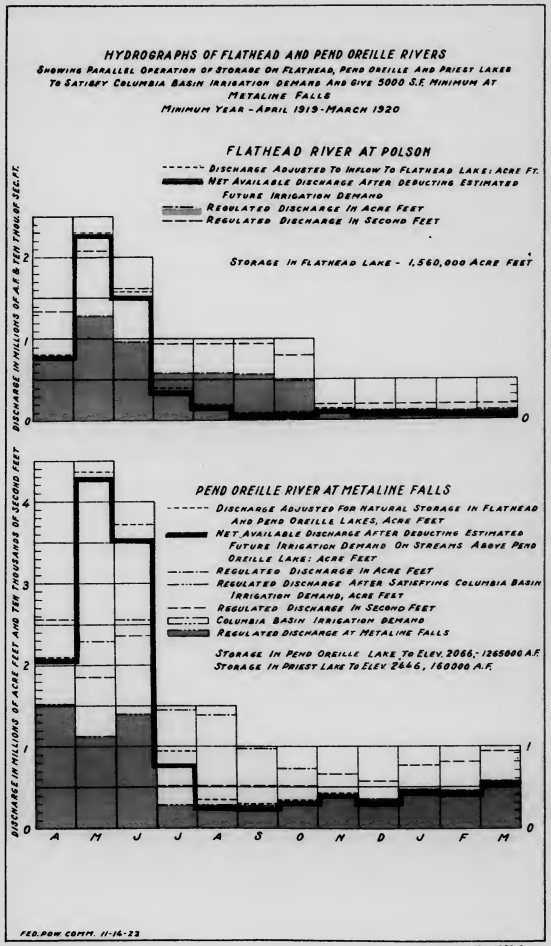
REGULATED DISCHARGE IN ACRE FEET
REGULATED DISCHARGE AFTER SATISFYING COLUMBIA BASIN IRRIGATION DEMAND, ACRE FEET
REGULATED DISCHARGE IN SECOND FEET
COLUMBIA BASIN IRRIGATION DEMAND
REGULATED DISCHARGE AT METALINE FALLS
STORAGE IN PEND OREILLE LAKE TO ELEV. 2066, - 1265000 A.F.
STORAGE IN PRIEST LAKE TO ELEV. 2446, 160000 A.F.
DISCHARGE IN MILLIONS OF ACRE FEET AND TEN THOUSANDS OF SECOND FEET
A M J J A S O N D J F M
FED POW COMM. 11-16-22
E. R. P. 1922 4837-G

HYDROGRAPHS OF FLATHEAD AND PEND OREILLE RIVERS

SHOWING PARALLEL OPERATION OF STORAGE ON FLATHEAD, PEND OREILLE AND PRIEST LAKES TO SATISFY COLUMBIA BASIN IRRIGATION DEMAND AND GIVE 5000 S.F. MINIMUM AT METALINE FALLS

MINIMUM YEAR - APRIL 1919-MARCH 1920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DISCHARGE IN MILLIONS OF A.F. & TEN THOUS. OF SEC. FT.
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PEND OREILLE RIVER AT METALINE FALLS
DISCHARGE ADJUSTED FOR NATURAL STORAGE IN FLATHEAD AND PEND OREILLE LAKES, ACRE FEET
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REGULATED DISCHARGE IN ACRE FEET
REGULATED DISCHARGE AFTER SATISFYING COLUMBIA BASIN IRRIGATION DEMAND, ACRE FEET
REGULATED DISCHARGE IN SECOND FEET
COLUMBIA BASIN IRRIGATION DEMAND
REGULATED DISCHARGE AT METALINE FALLS
STORAGE IN PEND OREILLE LAKE TO ELEV. 2066, - 1265000 A.F.
STORAGE IN PRIEST LAKE TO ELEV 2446, 160000 A.F.
DISCHARGE IN MILLIONS OF ACRE FEET AND TEN THOUSANDS OF SECOND FEET
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A M J J A S O N D J F M

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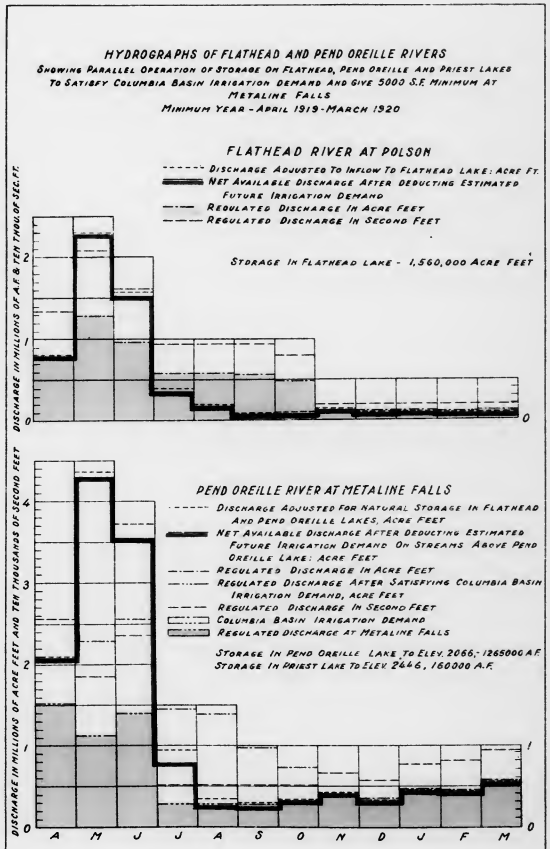
INTENTIONAL SECOND EXPOSURE

HYDROGRAPHS OF FLATHEAD AND PEND OREILLE RIVERS

SHOWING PARALLEL OPERATION OF STORAGE ON FLATHEAD, PEND OREILLE AND PRIEST LAKES TO SATISFY COLUMBIA BASIN IRRIGATION DEMAND AND GIVE 5000 S.F. MINIMUM AT METALINE FALLS

MINIMUM YEAR - APRIL 1919 - MARCH 1920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REGULATED DISCHARGE IN SECOND FEET
STORAGE IN FLATHEAD LAKE - 1,560,000 ACRE FEET
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PEND OREILLE RIVER AT METALINE FALLS
DISCHARGE ADJUSTED FOR NATURAL STORAGE IN FLATHEAD AND PEND OREILLE LAKES, ACRE FEET
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STORAGE IN PEND OREILLE LAKE TO ELEV. 2066, - 1265000 A.F.
STORAGE IN PRIEST LAKE TO ELEV. 2446, 160000 A.F.
DISCHARGE IN MILLIONS OF ACRE FEET AND TEN THOUSANDS OF SECOND FEET
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